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1930

SIXTY-FIRST ANNUAL REPORT

OF THE

SECRETARY

OF THE

State Board of Agriculture

OF THE

STATE OF MICHIGAN

AND

THIRTY-FIFTH ANNUAL REPORT

OF THE

EXPERIMENT STATION

FROM

JULY 1, 1921, TO JUNE 30, 1922

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LANSING, MICHIGAN
1923

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	Term Expires.
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JASON WOODMAN, Paw Paw	1st Monday January, 1924
*JOHN W. BEAUMONT, Detroit	1st Monday January, 1924
CLARK L. BRODY, Lansing	1st Monday January, 1924
MRS. DORA STOCKMAN, Lansing	1st Monday January, 1926
*JOHN A. DOELLE, Lansing	1st Monday January, 1928
MELVILLE B. McPHERSON, Lowell	1st Monday January, 1928
JAY R. McCOLL, Detroit	1st Monday January, 1928
DAVID FRIDAY, President of the College	Ex-Officio
THOMAS E. JOHNSON, Supt. of Public Instruction	Ex-Officio
*ADDISON M. BROWN, Secretary.	
HERMAN H. HALLADAY, Secretary.	
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*Resigned.

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(Under Control of the State Board of Agriculture.)

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George W. Bissell, M. E., Dean of Engineering.
Frank W. Chamberlain, B. S., D. V. M., Acting Dean of Veterinary Science; Professor of Anatomy.
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*Eudora H. Savage, B. S., Dean of Women.
William J. Beal, Ph. D., D. Sc., D. Agr., Professor of Botany, Emeritus.
Wilbur O. Hedrick, M. S., Ph. D., Professor of Economics.
Herman K. Vedder, C. E., Professor of Civil Engineering.
Walter B. Barrows, B. S., Professor of Zoology and Physiology; Curator of the General Museum.
Rufus H. Pettit, B. S. in Agr., Professor of Entomology.
*Addison M. Brown, A. B., Secretary of the College.
Herman H. Halladay, Secretary of the College.
Elida Yakeley, Registrar.
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Ward Giltner, D. V. M., M. S., Professor of Bacteriology and Hygiene.
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Ernst A. Bessey, Ph. D., Professor of Botany.
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Louis C. Plant, Ph. B., M. S., Professor of Mathematics.
Merris M. McCool, Ph. D., Professor of Soils.
Alfred K. Chittenden, M. F., Professor of Forestry.
Robert K. Steward, B. S., C. E., Professor of Drawing and Design.
Major Philip G. Wrightson, M. S., Professor of Military Science and Tactics.
Chester L. Brewer, B. P. E., Director of Physical Training.
Charles P. Halligan, B. S., Professor of Horticulture and Landscape Gardening.

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Joseph F. Cox, B. S. in Agr., Professor of Farm Crops.
Harry H. Musselman, B. S., Professor of Farm Mechanics.
Clyde Reynolds, M. D., Director of Health Service.
Howard M. Eliot, M. A., Professor of Farm Management.
Ollie E. Reed, M. S., Professor of Dairy Husbandry.
George A. Brown, B. S., Professor of Animal Husbandry.
Henry B. Dirks, B. S., M. E., Professor of Mechanical Engineering.
John S. Taylor, Director of Music.
Carl G. Card, Director Guidance School.
Chace Newman, Associate Professor of Drawing and Design.
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George H. Coons, A. M., Ph. D., Associate Professor of Botany in Charge of Plant Pathology.
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E. Sylvester King, Associate Professor of Public Speaking.
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Frank A. Spragg, B. S., M. S., Associate Professor of Farm Crops.
Winifred S. Gettemy, Associate Professor of Home Economics.
Marion L. Tucker, B. S., Associate Professor of Home Economics.
Rebekah M. Gibbons, B. S., M. S., Associate Professor of Home Economics.
Guy G. Speeker, A. M., Associate Professor of Mathematics.
Stanley E. Crowe, B. A., Associate Professor of Mathematics.
John T. Horner, M. A., Associate Professor of Economics.
Henrik J. Stafseth, D. V. M., Associate Professor of Bacteriology.
Oren L. Snow, B. S., Associate Professor of Physics.
Lola G. Yerkes, B. S., Associate Professor of Home Economics.

Thomas Gunson, Assistant Professor of Horticulture and Superintendent of Grounds.
Claude M. Cade, B. S., C. E., Assistant Professor of Civil Engineering.
Ren G. Saxton, C. E., Assistant Professor of Civil Engineering.
Dwight T. Ewing, Ph. D., Assistant Professor of Chemistry.
Edward F. Woodcock, M. A., Ph. D., Assistant Professor of Botany.
Walter E. Reuling, B. S. in M. E., Assistant Professor of Mechanical Engineering.
Howard E. Johnson, D. V. S., Assistant Professor of Comparative Anatomy.
John W. Steward, B. M. E., Assistant Professor of Drawing and Design.
Clive R. Megee, B. S., M. S., Assistant Professor of Farm Crops.
Russell A. Runnells, D. V. M., Assistant Professor of Animal Pathology.
Robert E. Loree, B. S., Assistant Professor of Horticulture.
Norma L. Roseboom, A. B., Assistant Professor of English.
Mary A. W. Hendrick, A. B., Assistant Professor of History and Political Science.
Eugenia I. McDaniel, A. B., Assistant Professor of Entomology.
Oliver A. Taylor, D. V. M., Assistant Professor of Anatomy.
Warren W. Hitchcock, B. S., C. E., Assistant Professor of Civil Engineering.
Burt K. Philp, C. E., Assistant Professor of Civil Engineering.
†Louise I. Clemens, B. S., Assistant Professor of Home Economics.
Henry L. Publow, B. S., Chem. E., Assistant Professor of Chemistry.
*Arthur L. Bibbins, B. S., Assistant Professor of Farm Crops.
Leo C. Hughes, A. M., Assistant Professor of English.
Perry S. Brundage, B. S., Assistant Professor of Chemistry.
Ray B. Weaver, M. A., Assistant Professor of English.
Omar M. Lebel, Ph. B., Assistant Professor of English.
I. Forest Huddleson, M. S., Assistant Professor of Bacteriology.
Osee Hughes, B. A., Assistant Professor of Home Economics.
Edwin Morrison, M. S., Assistant Professor of Physics.
Wallace L. Chandler, Ph. D., Assistant Professor of Entomology.
Edmund C. Sauve, B. S., Assistant Professor of Farm Mechanics.
Edward K. Sales, D. V. M., Assistant Professor of Surgery and Medicine.
Captain Joseph J. Teter, Assistant Professor of Military Science.
William E. J. Edwards, B. S. A., Assistant Professor of Animal Husbandry.
*Phillip L. Buttrick, M. F., Assistant Professor of Forestry.
Lawrence C. Wheeting, M. S., Assistant Professor of Soils.
Claude L. Brattin, B. M. E., Assistant Professor of Drawing and Design.
*Homer E. Dennison, B. S., Assistant Professor of Dairy Production.
Floyd E. Fogle, B. S. in Agr., Assistant Professor of Farm Mechanics.
Caroline L. Holt, Assistant Professor of Drawing and Design.
Walter L. Mallman, B. S., Assistant Professor of Bacteriology.
*Carl E. Newlander, B. S., Assistant Professor of Dairy Manufactures.
Newton L. Partridge, Ph. D., Assistant Professor of Horticulture.
May Person Kirby, A. B., Assistant Professor of Home Economics; Assistant to the Dean.
Godfrey L. A. Ruehle, M. S., Assistant Professor of Bacteriology.
Earle H. Stewart, B. S. in M. E., Assistant Professor of Drawing and Design.
George C. Wright, B. S. in M. E., Assistant Professor of Mechanical Engineering.
Frank E. Wood, Ph. D., Assistant Professor of Mathematics.

BRANSON A. WALPOLE, Assistant Professor of Education; Critic Teacher in Agriculture.
CHARLES E. CORMANY, M. S. in Agr., Assistant Professor of Farm Crops.
PAUL M. HARMER, Ph. D., Assistant Professor of Soils.
CHARLES D. BALL, B. S., Assistant Professor of Chemistry.
AVIS L. SPRAGUE, B. S., Assistant Professor of Home Economics.
DOROTHY SHANK, B. S., Assistant Professor of Home Economics.
VERNON G. GROVE, A. M., Assistant Professor of Mathematics.
GEORGE W. HOBBS, B. S., Assistant Professor of Mechanical Engineering.
JOSEPHINE R. HART, B. S., Assistant Professor of Home Economics Education; Critic Teacher in Home Economics.
EMMA P. GARRISON, B. S., Assistant Professor of Home Economics Education; Critic Teacher in Home Economics.
REUBEN T. TAYLOR, A. B., Assistant Professor of English.
PHILIP J. BAKER, B. S., Assistant Professor of Mechanical Engineering.

INSTRUCTORS AND OTHERS.

The names of instructors whose resignations took effect between June 30th and September 1st, 1921, do not appear below.

DEWEY A. SEELEY, M. A., Instructor in Meteorology.
BERTHA E. THOMPSON, M. A., Instructor in Botany.
LOUIS B. MAYNE, A. B., Instructor in English.
JOSEPH W. STACK, M. S., Instructor in Zoology.
STANARD G. BERGQUIST, A. B., Instructor in Zoology.
HARRY C. YOUNG, M. S., Instructor in Botany.
GEORGE J. POSTHUMUS, Instructor in Pattern Shop.
RUSSELL H. KELTY, B. S., Instructor in Entomology.
J. ROBERT DUNCAN, Instructor in Farm Crops.
HOWARD D. LIGHTBODY, M. S., Instructor in Chemistry.
EDWARD F. ELDRIDGE, B. S., Instructor in Chemistry.
†EDITH BUTLER, Instructor in Drawing and Design.
JUSTUS E. RISING, M. E., Instructor in Drawing and Design.
WALTER L. WATT, Instructor in Machine Shop Practice.
HELEN D. GRIMES, Instructor in Physical Training.
ALBERT H. NELSON, A. M., Instructor in English.
LYMAN L. FRIMODIG, B. S., Instructor in Physical Training.
DANIEL L. SHAFER, Instructor in Farm Mechanics.
ETHEL TAFT, B. S., Instructor in Home Economics.
OSCAR W. FAIRBANKS, B. S., Instructor in Drawing and Design.
DAVID T. MILLARD, Instructor in Pattern Making.
*WILSON E. NEWLON, B. S., Instructor in Poultry Husbandry.
RAYMOND L. BAXTER, B. S., Instructor in Chemistry.
JAMES DEVERS, Instructor in Physical Training.
EUGENE E. DOWN, B. S., Instructor in Farm Crops.
GEORGE A. GARRATT, B. S., Instructor in Forestry.
LOUIS G. GENTNER, M. S., Instructor in Entomology.
FLETCHER A. GOULD, B. S., Instructor in Civil Engineering.
JOHN G. HEPPINSTALL, Instructor in Physical Training.
RUFUS P. HIBBARD, Ph. D., Instructor in Botany.
EDWARD E. KINNEY, B. S., Instructor in Electrical Engineering.
HAROLD M. KREBS, B. S., Instructor in Chemistry.
JESSIE M. MACCORNACK, Instructor in Physical Training.

Clifford N. Rix, Instructor in Mechanical Engineering.
James E. Robertson, B. S., Instructor in Mathematics.
Wilbur H. Thies, B. S., Instructor in Physics.
Bert Sangster, Instructor in Mechanical Engineering.
Wilfred C. Lewis, M. A., Instructor in Chemistry.
Stanley Johnston, B. S., Instructor in Horticulture.
George W. Putnam, Instructor in Farm Crops.
Albert N. Barron, B. S., Instructor in Physical Training.
Gertrude Loudenback, Instructor in Physical Training.
George F. Davis, B. S., Instructor in Poultry Husbandry.
*Arthur H. Joel, B. S., Instructor in Soils.
Orville B. Price, B. S., A. M., Instructor in Soils.
Jule F. Nelson, B. S., Instructor in Home Economics.
Irma H. Gross, B. S., Instructor in Home Economics.
Ralph C. Huffer, M. A., Instructor in Mathematics.
Stanley J. Daley, A. B., Instructor in Mathematics.
Ralph Hammond, Instructor in Farm Mechanics.
Robert L. Tweed, B. S., Instructor in Bacteriology.
Lewis P. Waldo, M. A., Instructor in English.
Willard H. Bonner, A. B., A. M., Instructor in English.
Myrtle Maguire, Instructor in Guidance School.
George A. Trollope, Instructor in Guidance School.
James W. Milne, A. B., Instructor in English.
Patricia MacDonald, Instructor in Music.
Linda E. Landon, Librarian.
Lory F. Newell, Operating Engineer.
*Benjamin A. Faunce, Clerk to the President.
Edwyn A. Bowd, College Architect.
Andrew P. Krentel, Foreman of the Pattern Shop.
Jacob Schepers, Cashier.
Ralph S. Hudson, B. S., Farm Foreman.
Maud A. Meech, Chief Clerk to the Secretary.
Edward C. Crawford, Shop Engineer.
Cora L. Feldcamp, B. S., Reference Librarian.
Jacob A. Eicher, Foreman of Foundry.
Anna L. Ferle, Assistant Registrar.
Jesse J. Hendryx, Nursery Foreman.
Nancy L. Eastman, In Charge of College Residence.
Robert Mackie, Herdsman.
Nellie M. Campbell, Bookkeeper.
*Clifford W. McKibbin, M. S., M. F., Alumni Recorder.
Ashley M. Berridge, B. S., Director of Short Courses.
Sallie Katz, In Charge of Senior House.
Nora Field, In Charge of Waterbury House.
Frances Murdock, In Charge of College Cottage.
Willard N. Sweeney, Purchasing Agent.
Caroline S. Lewerenz, In Charge of Abbot Hall.
Mrs. W. B. Ratleff, In Charge of Howard Terrace.
Ralph M. Harford, College Photographer.
Ernest V. Hartman, B. A., Secretary Y. M. C. A., In Charge of Employment Bureau.
William Wise, Poultryman.
Daniel A. Shafer, Laboratory Foreman.

*May E. Foley, B. S., Assistant Alumni Recorder.
Elmer B. Hint, B. S., Superintendent of Official Testing.
James B. Hasselman, A. B., Publicity Agent.
Norman O. Weil, B. S., College Field Agent.
Earl A. Harlow, Storekeeper.
Marie LaPrelle, Matron College Hospital.
Marguerite Barker, Nurse, College Hospital.
George A. Getman, Field Foreman.
Marion L. Grettenberger, B. S., Assistant in Chemistry.
Elton B. Hill, B. S., M. S., Assistant to the Dean of Agriculture and Director of Experiment Station; Director of Short Courses.
Earl L. Hemmenway, A. B., Assistant in Economics.
Florence K. Middaugh, Ph. B., Assistant to the President.
Otto Friedemann, B. S., Graduate Assistant in Bacteriology.
Wilfred D. Mills, B. S., Graduate Assistant in Botany.
Hubert M. Brown, A. B., B. S., Graduate Assistant in Farm Crops.
Southard T. Flynn, A. B., Graduate Assistant in Entomology.

EXPERIMENT STATION.

Advisory and Assistant Staff.

Andrew J. Patten, B. S., Chemist.
George J. Bouyoucos, Ph. D., Research Professor of Soils.
Charles S. Robinson, Ph. D., Research Associate in Chemistry.
Orrin B. Winter, B. A., Research Associate in Chemistry.
Leslie H. Cooledge, M. A., Research Associate in Bacteriology.
I. Forest Huddleson, M. S., Research Associate in Bacteriology.
George M. Grantham, B. S. (½ time, balance Extension), Research Associate in Soils.
Charles H. Spurway, B. S. in Agr., Research Associate in Soils.
Ray Nelson, B. S., Research Associate in Plant Pathology.
Walter C. Dutton, B. S., Research Associate in Horticulture.
Robert M. Snyder, Ph. D., Research Assistant in Bacteriology.
John E. Kotila, M. S., Research Assistant in Plant Pathology.
Stanley J. Brownell, B. S., M. Agr., Research Assistant in Dairying.
Fred T. Riddell, B. S., Research Assistant in Farm Management.
Carlyle W. Bennett, M. S., Research Assistant in Plant Pathology.
H. R. Pettigrove, B. S., Research Assistant in Farm Crops (Upper Peninsula).
Jethro O. Veatch, A. B., Research Assistant in Soils.
Howard M. Wells, B. S., Research Assistant in Horticulture.
James Tyson, Research Assistant in Soils.
Elroy J. Miller, M. S., Assistant in Chemistry.
*Percy O'Meara, B. S., Assistant in Chemistry.
*William J. Kurtz, B. S., Assistant in Dairying.
Duane Rainey, B. S. (⅓ time only, balance Extension), Assistant in Farm Crops.
Selma Bandimer, B. S., Assistant in Chemistry.
Frank S. Davenport, B. S., Assistant in Bacteriology.
Dale T. Musselman, B. S., Assistant in Farm Management.
Guy E. Culver, B.S., Assistant in Farm Management.
Robert E. Post, B. S., Assistant in Farm Management.

Orville E. Dunckel, B. S., Assistant in Farm Management.
Howard N. Chapel, B. S., Assistant in Farm Management.
H. Donald Hootman, B. S., Superintendent of Graham Horticultural Experiment Station.
D. L. McMillan, Superintendent of Upper Peninsula Experiment Station.
Myra V. Bogue, Bulletin Clerk.

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*Resigned.

†Absent on leave.

AGRICULTURAL EXPERIMENT STATION

OF THE

MICHIGAN AGRICULTURAL COLLEGE

(Under the control of the State Board of Agriculture.)

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Rufus Hiram Pettit, B. S. A.	Entomologist
Andrew Jarvis Patten, B. S.	Chemist
Ernst Athearn Bessey, Ph. D.	Botanist
Ward Giltner, D. V. M., M. S.	Bacteriologist
Alfred Knight Chittenden, M. F.	Forester
Merris Mickey McCool. Ph. D.	Soil Physicist
Charles Parker Halligan, B. S.	Horticulturist
George Arthur Brown, B. S.	Animal Husbandman
Harry Hayes Musselman, B. S.	Farm Mechanics
Elam Tandy Hallman, D. V. M.	Animal Pathologist
Joseph Frank Cox, B. S. A.	Farm Crops
Ollie Ezekiel Reed, M. S.	Dairy Husbandman
Howard McKenny Eliot, M. A.	Farm Management
Ernest Clifford Foreman, B. S. A.	Poultry Husbandman
Elton Brainard Hill, B. S.	Assistant to Director
Herman H. Halladay	Secretary

COOPERATIVE EXTENSION WORK IN AGRICULTURE AND HOME ECONOMICS

ADMINISTRATIVE OFFICE.

Robert James Baldwin, B. S.	Director of Extension Work
Hale Tennant, B. S.	Assistant Extension Director in charge of County Agents and Markets
Karl H. McDonel, B. S.	Assistant to Director

EXTENSION SPECIALISTS

James Blood Hasselman, A. B	Publicity
James Aaron Waldron, B. S	Dairying
Donald Williams, B. S	Sheep Husbandry
G. W. Putnam, B. S	Farm Crops
Howard C. Rather, B. S	Farm Crops
Duane F. Rainey, B. S	Farm Crops
Henry C. Moore, B. S	Potatoes and Vegetables
Russel M. Hain, B. S	Insect Pests
Edwin Ewell	Apiculture
Orsel Edwin Robey, B. S	Drainage
T. A. Farrand	Horticulture
H. B. Killough, M. S	Farm Management Demonstrator
L. F. Livingston, B. S	Land Clearing
A. C. Baltzer, B. S	Dairying
Paul M. Harmer, Ph. D	Soils
C. M. Ferguson, B. S	Poultry Husbandry
Gifford Patch, B. S	Assistant in Marketing
Willard C. Cribbs	Assistant in Marketing
Louise H. Campbell, B. S	State Leader, Home Economics
Edna Viola Smith, B. S	Home Management
Mariel Hopkins, B. S	Nutrition
Helen Arms, B. S	Household Arts

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C. V. Ballard, B. S	Assistant State Leader of County Agents
J. W. Weston, B. S	Assistant State Leader of County Agents
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Chris. Peter Johnson, B. S	Alger
Clyde O. T. Scheetz, B. S	Alpena
Leon L. Drake, B. S	Antrim and Kalkaska
Lester Vance Benjamin, B. S	Baraga
Frank W. Bennett	Barry
Claude Lawrence Nash, B. S	Branch
James Lewis Kraker, B. S	Benzie
F. L. Simanton, B. A., M. S	Berrien
E. L. Kunze, B. S	Cass
R. M. Roland, B. S	Calhoun
T. R. Shane, B. S	Chippewa
Don B. Jewell, B. S	Cheboygan
Howard Victor Kittle, B. S	Clinton
R. D. Bailey, B. S	Crawford
Karl Harold Miller, B. S	Dickinson
Ralph W. Tenny, B. S	Eaton
D. C. Cavanaugh, B. S	Emmet
Sidney Samuel Smith, B. S	Genesee

Charles Edwin Atwater, B. S	Gladwin
Carl Edwin Gunderson, B. S	Gogebic
John Wilson Sims, B. S	Hillsdale
Leo M. Geismer	Houghton
E. E. Twing	Huron
W. Floyd Manby, B. S	Iron
Roy E. Decker, B. S	Jackson
Ralph Leslie Olds, B. S	Kalamazoo
Keats K. Vining, B. S	Kent
A. J. Patch, B. S	Lapeer
Victor Carlton Vaughan, B. S	Leelanau
Ralph J. Carr, B. S	Lenawee
Fred S. Dunks, B. S	Livingston
Roy Harry Cameron, B. S	Luce
Kris Paul Bemis, B. S	Mason
Carl H. Knopf, B. S	Manistee
William Murphy, B. S	Macomb
Lee Roy Walker, B. S	Marquette
B. Eldon Shaffer, B. S	Montcalm
Irving Kirshman, B. S	Menominee
Ira Benona McMurtry	Midland
Paul H. Smith, B. S	Missaukee
Murray F. Jackson	Mecosta
Dwight Clark Long, B. S	Muskegon
Clair Taylor	Newaygo
Irving T. Pickford, B. S., M. Hort	Oceana
William Edward McCarthy, B. S	Ogemaw
Charles Benjamin Cook, B. S	Oakland
Arthur Clinton Lytle, B. S	Otsego
Clinton Pomeroy Milham, B. S	Ottawa
C. M. McCrary, B. S	Presque Isle
Arthur Grant Bovay, B. S	Saginaw
John D. Martin, B. S	Sanilac
Carl May Kidman, B. S	St. Clair
J. Vernon Sheap	Shiawassee
Alem John Hutchins, B. S	St. Joseph
Alexander MacVittie, B. S	Tuscola
Wesley Clare Eckard	Van Buren
Orestes Isaiah Gregg, B. S	Wayne
William Frederick Johnston, B. S	Wexford
Harold Scott Osler, B. S	Washtenaw

HOME DEMONSTRATION AGENTS.

Louise H. Campbell, B. S	State Home Demonstration Agent Leader
Aurelia Belle Potts, B. S	Assistant State Leader
Bernice Jennie Woodworth, B. S	Allegan
Helen Columbia Pratt, B. S	Chippewa
Blanche Clark	Kalamazoo
Eva Carrett, B. S	Oakland
Marion H. Rogers, B. S	Wayne
Sylvia Wixom, B. S	Marquette

Eva Schurr, B. S	Ottawa
Muriel Dundas, B. S	Gladwin
Jennie Williams, B. S	Gogebic

BOYS' AND GIRLS' CLUB WORK.

Ray A. Turner, B. S	State Club Leader
Barbara Van Heulen, B. S	Assistant State Club Leader
Elda Iantha Robb, B. S	Assistant State Club Leader
Ruth M. Creswell, B. S	Assistant State Club Leader
Arne Gerald Kettunen, B. S	Assistant State Club Leader

COUNTY CLUB LEADERS.

K. P. Silberg	Gogebic
Viva Lorene Osborn	Branch
Charles Ernest Ackley	Calhoun
Ann Rosale Banks	Cheboygan
Mary V. Hall	Iron
Marjorie E. Place	Lenawee
Harold Canfield, B. S	Macomb
Arthur Lawrence Strang, B. S	Saginaw
Beryl Otto Hagerman, B. S	Washtenaw
Lawrence W. Ross, B. S	Wayne
George Kimball, B. S	Oakland

ACCOUNT OF THE

MICHIGAN AGRICULTURAL COLLEGE

FOR THE YEAR ENDING JUNE 30, 1922

SECRETARY'S FINANCIAL REPORT

July 1, 1921.	Cash on hand			$12,199 86	
July 1, 1921.	Cash overdrawn College Treasurer				$21,868 17
June 30, 1922.	To special appropriations receipts			468,287 07	
	From State Treasurer		$268,938 94		
	Vocational teacher training	$13,948 22			
	Shops and storehouse 1/5 mill tax	24,990 72			
	Experiment Station 1/5 mill tax	90,000 00			
	Extension 1/5 mill tax	70,000 00			
	Extension, Sec. 1, Act 1921	70,000 00			
	From U. S. Treasurer		181,585 39		
	Experiment Station	$30,000 00			
	Extension	151,585 39			
	Other sources, including interdept. and transfers		17,762 74		
	By disbursements				528,097 49
	Special appropriations		22,215 67		
	Experiment Station		239,136 65		
	Extension		266,745 17		
	To current account receipts			885,847 60	
	From State Treasurer, land grant int.		70,838 32		
	State Treasurer 1/5 mill tax...(a)		815,009 28		
	From U. S. Treasurer, Morrill Fund			50,000 00	
	Institution and other sources including interdept.			317,472 45	
	By general account disbursements				1,237,058 30
	Cash on hand				5,375 94
	Cash overdrawn College Treasurer			58,592 92	
				$1,792,399 90	$1,792,399 90

(a) Total mill tax	$1,000,000 00
Amount set aside Experiment	90,000 00
Amount set aside Extension	70,000 00
Amount set aside Shops and Storehouse	24,990 72

TABLE NO. 1.—*Tabular Exhibit of Secretary's Report.*

	Balance sheet, July 1, 1921.		Transactions July 1, 1921.		Balance sheet, June 30, 1922.	
	Dr.	Cr.	Dr.	Cr.	Dr.	Cr.
Cash	$12,199 86		$6,823 92		$5,375 94	
(a) College Treasurer		$21,868 17	36,724 75			$58,592 92
Special Appropriations	28,902 32		43,708 99	$21,921 85	7,115 18	
Current Accounts		20,013 64	1,195,510 56	1,186,841 50		28,682 70
Experiment Station			131,082 46	234,458 69	103,376 23	
Extension	779 63		293,376 30	264,004 94		28,591 73
Interdept. Transfer			57,928 81	57,928 81		
Total	$41,881 81	$41,881 81	$1,765,155 79	$1,765,155 79	$115,867 35	$115,867 35

(a) Treasurer's statement is greater July 1, 1921, by $23,443.36 and June 30, 1922, by $70,549.95. Warrants outstanding and deposit in transit.

TREASURER'S ACCOUNT.

	Dr.	Cr.
Balance on hand July 1, 1921	$1,575 19	
Receipts from State Treasurer and Secretary of the College	$1,669,407 29	
Interest on deposits during the year	1,094 94	
Warrants paid July 1, 1921, to June 30, 1922		$1,660,120 39
Balance on hand June 30, 1922		11,957 03
Total	$1,672,077 42	$1,672,077 42

TABLE NO. 2.—*Statement of special appropriation accounts for the fiscal year ending June 30, 1922.*

	Balance of accounts, July 1, 1921.		Receipts.		Total available.	Total expended.	Balance of accounts June 30, 1922.	
	Dr.	Cr.	From State Treasurer.	From institution and other sources.			Dr.	Cr.
Experiment Station			(a)$120,000 00	$11,169 39	$131,169 39	$239,136 65	$107,967 26	
Extension	$779 63		(b) 291,585 39	1,823 30	292,629 06	266,745 17		$25,883 89
Nursery License				3 00	3 00	3 00		
Shops and Storehouse	25,218 21		24,990 72	426 15	196 66	198 66		
New Library Building					69 50	69 50		
Home Economics Building					408 58	408 58		
Vocational Teacher Training	4,277 54		13,948 22	3 40	9,674 08	16,910 54	7,236 46	
Sayer Fund		24 70		25 00	49 70	25 00		24 70
G.E. Lawson Memorial Prize	12 50			37 50	25 00	25 00		
G. L. Allen Scholarship		161 38		25 00	186 38			186 38
M. A. C. Scholarship				4,140 00	4,140 00	3,817 89		322 11
Marilla Griswold Scholars'p		206 17		110 00	316 17	250 00		66 17
Weather Service		213 68			213 68	213 68		
Total	$30,287 88	$605 93	$450,524 33	$17,762 74	$439,081 20	$527,803 67	$115,203 72	$26,483 25

(a) $30,000.00 U. S. Treasurer.
(b) $151,585.39 U. S. Treasurer

TABLE NO. 3.—*William Smith Sayer Scholarship Fund.*

	Year ending June 30.	Income.	Income expended to.	Amount.	Balance including principal.
$500.00 received of F. F. Sayer, administrator of the estate of William Smith Sayer, to establish scholarship in bacteriology..............	1910	$32 25	A. McVittie........	$19 75	$512 50
	1911	37 50	....	....	550 00
	1912	12 50	D. K. Fisher...... H. D. Wright....	25 00 25 00	512 50
	1913	25 00	D. Francisco......	25 00	512 50
	1914	24 85	R. W. Waffle......	25 00	512 35
	1915	24 85	J. D. Baker.......	25 00	512 20
	1916	25 00	J. M. Maze........	25 00	512 20
	1917	25 00	Elsa Scheuren.....	25 00	512 20
	1918	25 00	....	....	537 20
	1919	25 00	Elwyn Younker.. Ethel Hopphan...	25 00 25 00	512 20
	1920	25 00	Esther Severance..	25 00	512 20
	1921	37 50	Thelma Porter....	25 00	524 70
	1922	25 00	H. E. Segelin.....	25 00	524 70
Total..........................	....	$344 45	....	$319 75	....

TABLE NO. 4.—*Geo. E. Lawson Memorial Prize.*

	Year ending June 30.	Income.	Income expended to.	Amount.	Balance including principal.
$500.00 received of John W. Beaumont in memory of Geo. E. Lawson, to offer annual cash prize for the best essay in English produced by male student........................	1917	$25 00	I. B. McMurtry...	$25 00	$500 00
	1918	12 50	H. C. Diehl.......	25 00	487 50
	1919	25 00	Stanley Powell....	25 00	487 50
	1920	25 00	Fred F. Henshaw..	25 00	487 50
	1921	25 00	H. E. Segelin......	25 00	487 50
	1922	37 50	C. R. Clausen.....	25 00	500 00
Total..........................	....	$150 00	....	$150 00	....

TABLE No. 5.—*Geo. L. Allen Scholarship.*

	Year ending June 30.	Income.	Income expended to.	Amount.	Balance including principal.
$1,000.00 received of Amanda A. Ransom to be used in assisting the poor and deserving young men in obtaining their education...............	1919	....	....	....	$1,036 38
	1920	$50 00	....	....	1,086 38
	1921	75 00	....	....	1,161 38
	1922	25 00	....	....	1,186 38
Total..........................	....	$150 00	....	....	....

TABLE NO. 6.—*Marilla Griswold Scholarship.*

	Year ending June 30.	Income.	Income expended to.	Amount.	Balance including principal.
$2,000.00 received of Orion S. Cross, Executor of the estate of Marilla Griswold, the income of the same to be used under the direction of the State Board of Agriculture to help needy students. Preference to be given to those from Allegan County.	1920	$110 00	....	$13 83	$2,096 17
	1921	110 00	....	....	2,206 17
	1922	110 00	Emma Culver.....	250 00	2,066 17
Total..........................	....	$330 00	....	$263 83	....

TABLE NO. 7.—*M. A. C. Scholarship.*

	Year ending June 30.	Income.	Income expended to.	Amount.	Balance including principal.
$4,000.00 derived from daily balances of the M. A. C. trust funds and exchange charges collected at office. Income to be given that man and that woman respectively who shall have shown best scholastic records...	1922	$140 00	....	....	$4,140 00
Total..........................	....	$140 00	....	....	....

TABLE NO. 8.—*Current Account July 1, 1921, to June 30, 1922.*

On account of—	Dr. To disbursements.	Cr. By receipts.
U. S. Treasurer, 32d annual payment under Act of Congress of August, 1890	....	$50,000 00
State Treasurer, one-fifth mill fund	....	815,009 28
State Treasurer, interest on proceeds of sale of U. S. land grant	....	70,838 32
Agricultural Education	$916 83	2 25
Anatomy	12,395 11	359 33
Animal Husbandry	27,934 76	8,260 03
Bacteriology	21,057 43	5,070 95
Botany	28,072 04	1,592 66
Chemistry	58,756 86	14,554 90
Civil Engineering	25,596 44	615 00
Dairy Husbandry	65,933 60	47,503 20
Drawing and Design	32,996 36	1,502 44
Economics	13,950 01	21 00
Electrical Engineering	16,713 50	495 14
English	32,840 81	62 05
Entomology	15,998 82	507 80
Farm Crops	18,922 63	198 42
Farm and Horses	39,207 30	17,466 46
Farm Mechanics	15,584 76	1,375 62
Farm Management	4,511 60	72 35
Forestry	16,351 33	5,161 62
History	7,980 10	7 00
Horticulture	18,905 81	3,289 45
Home Economics	46,426 33	6,325 93
Library	11,152 57	71 03
Mathematics	27,338 20	349 50
Mechanical Engineering	37,880 69	3,480 57
Meteorology	600 50	15 00
Military Science	5,869 48	316 74
Music	8,072 52	3,399 75
Pathology	4,837 21	5 00
Physics	22,555 87	3,096 11
Physical Training	29,433 95	4,106 98
Poultry	14,187 83	3,637 51
Soils	11,289 43	425 23
Special Courses	11,409 28	2,754 75
Surgery and Clinic	11,171 26	1,274 47
Zoology	19,021 36	1,070 80
Applied Science	5,985 39	....
Purchase and Rental of Lands	1,773 78	3,366 00
Advertising	7,580 17	25 00
Alumni Recorder	4,342 84	....
Cleaning	17,613 82	95 47
Commencement	655 45	....
Convocations	578 29	....
Dean of Agriculture	4,791 81	4 50
Dean of Engineering	7,685 12	18 35
Dean of Summer School	14,551 33	....
Dean of Women	22,500 89	557 75
Diplomas	696 47	1,250 00
Electric Lights	12,158 70	2,337 85
Expense of Board Members	1,079 28	....
Federal Students	11,888 12	13,447 66
Freight and Cartage	6,068 28	225 26
Fire Equipment	171 28	....
General	14,919 41	10 50
General Lectures	75 00	....
Heating	65,569 68	1,454 72
Health Service	11,986 52	7,251 51
Maintenance and Repair of Buildings	69,081 88	(a) 122,001 21
Maintenance of Grounds	9,347 82	60 26
New Buildings and Additions	101,627 88	936 58
Office of President	14,308 96	2,475 76
Office of Secretary	28,111 78	537 77
Registrar	9,148 76	....

TABLE NO. 8.—*Current Account July 1, 1921, to June 30, 1922*—Concluded.

On account of—	Dr. To disbursements.	Cr. By receipts.
Telephone	$2,629 76	$311 35
Store	49,908 97	20,309 12
Fairs	3,619 21	902 02
Miscellaneous	729 07	1,446 77
Total	$1,237,058 30	$1,253,320 05
Balance beginning fiscal year, July 1, 1921	....	20,013 64
Balance on hand June 30, 1922	28,682 70	....
Total	$1,265,741 00	$1,273,333 69

(a) Supplies, $4,536.64; sundry, $2,059.37; incidental, $66,674.00; room rent, $30,923.99; tuition, $4,436.50; rental, $908.00; matriculation, $3,285.00; labor, $9,107.71; delinquent, $70.00.

TABLE NO. 8.—*Distribution of Special Appropriations.*

	Dr. To disbursements.	Cr. By Receipts.
Nursery License and Inspection	$3 00	$3 00
Weather Service	213 68	....
Sayer Fund	25 00	25 00
G. E. Lawson Memorial Fund	25 00	37 50
Geo. L. Allen Scholarship	....	25 00
Marilla Griswold Scholarship	250 00	110 00
M. A. C. Scholarship	3,817 89	4,140 00
Vocational Teacher Training	16,921 77	13,951 62
Shops and Storehouse	389 57	25,416 87
New Library Building	69 50	....
Home Economics Building	500 26	....
Total	$22,215 67	$43,708 99
Balance overdrawn July 1, 1921	28,902 32	....
Balance overdrawn July 1, 1922	....	7,409 00
Total	$51,117 99	$51,117 99

TABLE NO. 9.—*Experiment Station Account for Fiscal Year Ending June 30, 1922.*

	Disbursements.			Dr. total disbursements each department.	Cr. receipts.
	Adams.	Hatch.	State.		
Balance on hand July 1, 1921					
United States Treasurer					$30,000 00
State Treasurer, one-fifth mill fund					90,000 00
Fertilizer fees			$263 91	$263 91	
Commercial Feeding Stuffs					40 00
Animal Husbandry		$345 00	2,240 28	2,585 28	1,654 69
Bacteriology	$445 80	157 29	7,962 64	8,565 73	231 02
Botany		143 11	3,575 15	3,718 26	
Chemistry			2,165 69	2,165 69	90 00
Dairy Husbandry			38 97	38 97	180 22
Director's Office			13,762 17	13,762 17	171 50
Entomology			1,358 95	1,358 95	21 00
Farm Crops		1,165 69	10,821 62	11,987 31	2,317 59
Forestry			415 41	415 41	
Farm Management			3,597 76	3,597 76	
Farm Mechanics			1,334 64	1,334 64	
Horticulture			4,799 18	4,799 18	
Library			406 68	406 68	
Salaries	14,554 20	12,947 75	105,314 97	132,816 92	
Soils		241 16	12,115 15	12,356 31	5 61
Graham Hort. Station			8,951 20	8,951 20	1,032 31
South Haven Station			4,867 74	4,867 74	731 91
U. P. Station			25,144 54	25,144 54	4,693 54
Balance June 30, 1922					
Total	$15,000 00	$15,000 00	$209,136 65	$239,136 65	$131,169 39

TABLE NO. 10.—*Extension Account for Fiscal Year Ending June 30, 1922.*

	Disbursements.			Dr. total disbursements for each project.	Cr. by receipts.
	Lever.	Lever State.	State.		
Balance July 1, 1921				$779 63	
U. S. Treasurer Lever Fund					$151,585 39
State Treasurer, Act 250, 1921					70,000 00
State Treasurer, one-fifth mill Extension Fund, State					70,000 00
Administration	$3,462 50	$12,196 64	$2,153 96	$17,813 10	208 06
Boys and Girls Club	23,209 16	397 13	10,565 89	34,172 18	517 63
Control Insect Pests	785 75	2,903 28	1,613 85	5,302 88	
Country Agents	84,777 78	196 20	3,901 84	88,875 82	30 00
Fairs					
Farm Crops	4,380 48	4,600 40	5,100 24	14,081 12	07
Farm Management	650 00	2,075 41	1,841 39	4,566 80	386 10
Home Demonstration Agents	11,704 50	53 63	2,488 42	14,246 55	23 30
Home Economics	11,811 95	111 03	5,169 45	17,092 43	115 65
Horticulture	800 00	2,462 76	1,748 19	5,010 95	87
Household Engineering	800 00	2,466 99	1,243 08	4,510 07	
Live Stock	2,638 10	7,686 90	4,304 33	14,629 33	489 75
Markets	2,800 00	7,756 55	7,597 36	18,153 91	20 00
Muck Crops					
Potatoes and Vegetables	1,571 42	2,563 04	1,436 97	5,571 43	
Poultry	625 00	1,957 89	1,779 47	4,362 36	31 70
Publications		36 57	4,401 27	4,437 84	
Soils	668 75	1,926 84	1,362 84	3,958 43	17
Land Clearing	900 00	2,442 32	4,087 64	7,429 96	
Lectures			2,530 01	2,530 01	
Balance on hand June 30, 1922				25,883 89	
Total	$151,585 39	$51,833 58	$63,326 20	$293,408 69	$293,408 69

TABLE NO. 11.—*Positions and salaries as shown by pay-roll dated June 30, 1922.*

	Rate per year.	Classification.		Extension.
		Current.	Experiment Station.	
ADMINISTRATION AND MISCELLANEOUS.				
President's Office:				
President	$12,000 00	$12,000 00		
Assistant to President	3,000 00	3,000 00		
Clerk to President	1,700 00	1,700 00		
Secretary's Office:				
Secretary	6,000 00	5,500 00	$500 00	
Cashier and Assistant Secretary	3,600 00	3,100 00	500 00	
Bookkeeper	1,700 00	1,300 00	400 00	
Chief Clerk	2,600 00	850 00		1,750 00
Clerk	1,700 00	1,700 00		
Clerk	1,400 00	1,400 00		
Clerk	1,400 00	1,400 00		
Clerk	1,400 00	1,400 00		
Purchasing Agent	2,800 00	2,800 00		
Registrar's Office:				
Registrar	3,000 00	3,000 00		
Assistant	2,000 00	2,000 00		
Clerk	1,300 00	1,300 00		
Library:				
Librarian	2,800 00	2,400 00	400 00	
Assistant	1,800 00	1,800 00		
Assistant	1,400 00	1,400 00		
Reference Librarian	2,000 00	2,000 00		
Advertising:				
Agent, Field	3,000 00	3,000 00		
Agent, Publicity	3,200 00	1,000 00		2,200 00
Miscellaneous:				
Engineer	2,800 00	2,800 00		
Night Watchman	1,300 00	1,300 00		
Architect	3,500 00	3,500 00		
Employment Bureau	500 00	500 00		
Health Service:				
Medical Officer	3,500 00	3,500 00		
Secretary	1,600 00	1,600 00		
Nurse	1,600 00	1,600 00		
Matron	1,300 00	1,300 00		
Meteorology:				
Instructor	600 00	600 00		
Stores:				
Storekeeper	1,800 00	1,800 00		
Clerk	1,200 00	1,200 00		
Division of Home Economics:				
Dean	5,500 00	4,000 00		V. 1,500 00
Assistant to Dean	3,000 00	3,000 00		
Associate Professor	2,800 00	2,800 00		
Associate Professor	2,800 00	2,800 00		
Associate Professor	3,175 00	3,175 00		
Associate Professor	2,800 00	2,800 00		
Associate Professor	3,000 00	3,000 00		
Associate Professor	3,200 00	3,200 00		
Assistant Professor	3,250 00	3,250 00		
Assistant Professor	2,400 00	2,400 00		
Assistant Professor	3,000 00	3,000 00		
Assistant Professor	2,600 00	1,600 00		V. 1,000 00
Instructor	1,800 00	1,800 00		
Instructor	1,800 00	1,800 00		
Clerk	1,500 00	1,500 00		

TABLE NO. 11—*Continued.*

	Rate per year.	Classification.		Extension.
		Current.	Experiment Station.	
Dean of Women:				
Dean	$3,600 00	b$3,600 00		
Matron	1,500 00	b 1,500 00		
Matron	1,000 00	b 1,000 00		
Matron	1,000 00	b 1,000 00		
Matron	850 00	b 850 00		
Matron	850 00	b 850 00		
Matron	850 00	b 850 00		
Farm Management:				
Professor	4,250 00	2,125 00	$2,125 00	
Research Assistant	2,800 00		2,800 00	
Assistant	1,600 00		1,600 00	
Assistant	1,800 00		1,800 00	
Assistant	1,800 00		1,800 00	
Assistant	1,800 00		1,800 00	
Assistant	1,800 00		1,800 00	
Clerk	1,200 00		1,200 00	
Stenographer	1,200 00	600 00		600 00
DIVISION OF ENGINEERING.				
Dean's Office:				
Dean	5,500 00	a 5,500 00		
Secretary	1,500 00	1,500 00		
Department of Drawing and Design:				
Professor	5,000 00	5,000 00		
Associate Professor	3,200 00	3,200 00		
Associate Professor	3,600 00	3,600 00		
Associate Professor	3,200 00	3,200 00		
Assistant Professor	2,600 00	2,600 00		
Assistant Professor	2,600 00	2,600 00		
Assistant Professor	2,500 00	2,500 00		
Assistant Professor	2,400 00	2,400 00		
Instructor	2,200 00	2,200 00		
Instructor	2,200 00	2,200 00		
Instructor	1,800 00	1,800 00		
Stenographer	1,300 00	1,300 00		
Department of Civil Engineering:				
Professor	4,000 00	a 4,000 00		
Associate Professor	3,200 00	3,200 00		
Assistant Professor	2,800 00	2,800 00		
Assistant Professor	2,500 00	2,500 00		
Assistant Professor	2,600 00	2,600 00		
Assistant Professor	2,800 00	2,800 00		
Instructor	2,000 00	2,000 00		
Stenographer	1,100 00	1,100 00		
Department of Mechanical Engineering:				
Professor	4,250 00	4,250 00		
Assistant Professor	2,800 00	2,800 00		
Assistant Professor	2,600 00	2,600 00		
Assistant Professor	2,600 00	2,600 00		
Assistant Professor	2,400 00	2,400 00		
Instructor	1,800 00	1,800 00		
Instructor	2,200 00	2,200 00		
Instructor	2,200 00	2,200 00		
Instructor	2,000 00	2,000 00		
Instructor	2,000 00	2,000 00		
Instructor	2,400 00	2,400 00		
Tool Room Attendant	1,900 00	1,900 00		
Shop Engineer	1,500 00	1,500 00		
Stenographer	600 00	600 00		
Department of Electrical Engineering:				
Professor	4,500 00	4,500 00		
Associate Professor	3,200 00	3,200 00		
Associate Professor	3,200 00	3,200 00		
Instructor	2,000 00	2,000 00		
Stenographer	600 00	600 00		

TABLE NO. 11—*Continued.*

	Rate per year.	Classification.		Extension.
		Current.	Experiment Station.	
DIVISION OF SCIENCE AND LETTERS.				
Applied Science:				
Dean	$6,000 00	$6,000 00		
Department of Federal Students:				
Director	2,400 00	2,400 00		
Instructor	2,000 00	2,000 00		
Instructor	1,200 00	1,200 00		
Department of Bacteriology:				
Professor	4,750 00	3,150 00	$1,600 00	
Associate Professor	3,200 00	2,400 00	800 00	
Associate Professor	3,200 00	1,600 00	1,600 00	
Assistant Professor	2,500 00	2,500 00		
Instructor	2,400 00	800 00	1,600 00	
Graduate Assistant	800 00	800 00		
Research Associate	3,600 00		3,600 00	
Research Assistant	2,800 00		2,800 00	
Assistant	1,500 00		1,500 00	
Assistant	3,200 00	1,000 00	2,200 00	
Assistant	3,400 00	1,200 00	2,200 00	
Department of Botany:				
Professor	4,500 00	a 3,600 00	900 00	
Associate Professor	3,500 00	3,500 00		
Associate Professor	3,800 00	1,900 00	1,900 00	
Associate Professor	3,000 00	3,000 00		
Assistant Professor	2,800 00	700 00	2,100 00	
Assistant Professor	2,400 00	2,400 00		
Assistant Professor	2,400 00	1,200 00	1,200 00	
Instructor	2,800 00	700 00	2,100 00	
Instructor	1,700 00	1,700 00		
Graduate Assistant	800 00	800 00		
Stenographer	1,350 00	900 00	450 00	
Research Assistant	2,400 00		2,400 00	
Research Assistant	2,600 00		2,600 00	
Department of Chemistry:				
Professor	5,000 00	5,000 00		
Associate Professor	3,800 00	3,800 00		
Associate Professor	3,800 00	3,800 00		
Associate Professor	3,200 00	3,200 00		
Assistant Professor	2,600 00	2,600 00		
Assistant Professor	3,000 00	3,000 00		
Assistant Professor	2,800 00	2,800 00		
Assistant Professor	2,400 00	2,400 00		
Instructor	2,000 00	2,000 00		
Instructor	2,200 00	2,200 00		
Instructor	2,400 00	2,400 00		
Instructor	2,200 00	2,200 00		
Instructor	1,800 00	1,800 00		
Instructor	1,800 00	1,800 00		
Clerk	1,300 00	1,300 00		
Dispensing Clerk	1,800 00	1,800 00		
Department of Economics:				
Professor	4,500 00	4,500 00		
Associate Professor	3,600 00	3,600 00		
Associate Professor	3,800 00	3,800 00		
Assistant	2,400 00	2,400 00		
Stenographer	1,350 00	675 00	675 00	
Department of English:				
Professor	4,000 00	a 4,000 00		
Associate Professor	3,400 00	3,400 00		
Assistant Professor	2,800 00	2,800 00		
Assistant Professor	2,600 00	2,600 00		
Assistant Professor	2,600 00	2,600 00		
Assistant Professor	2,400 00	2,400 00		
Assistant Professor	2,600 00	2,600 00		
Instructor	1,800 00	1,800 00		
Instructor	2,300 00	2,300 00		
Instructor	1,800 00	1,800 00		
Instructor	1,800 00	1,800 00		

TABLE NO. 11—*Continued.*

	Rate per year.	Classification.		Extension.
		Current.	Experiment Station.	
Department of Entomology:				
Professor	$4,700 00	(a)$3,100 00	$1,600 00	
Assistant Professor	3,000 00	1,600 00	1,400 00	
Assistant Professor	3,400 00	1,900 00	1,500 00	
Instructor	2,300 00	2,300 00		
Instructor	2,000 00	2,000 00		
Stenographer	1,200 00	1,200 00		
Graduate Assistant	800 00	800 00		
Department of History:				
Professor	5,000 00	5,000 00		
Assistant Professor	2,500 00	2,500 00		
Department of Mathematics:				
Professor	5,000 00	5,000 00		
Associate Professor	3,800 00	3,800 00		
Associate Professor	3,200 00	3,200 00		
Assistant Professor	3,300 00	3,300 00		
Assistant Professor	2,400 00	2,400 00		
Assistant Professor	2,600 00	2,600 00		
Instructor	1,800 00	1,800 00		
Instructor	2,200 00	2,200 00		
Instructor	2,100 00	2,100 00		
Department of Military Science:				
Professor	2,450 00	2,450 00		
Instructor	500 00	500 00		
Armorer	1,300 00	1,300 00		
Department of Music:				
Director	3,500 00	3,500 00		
Instructor	1,200 00	1,200 00		
Department of Physics:				
Professor	4,500 00	4,500 00		
Associate Professor	3,200 00	3,200 00		
Associate Professor	3,200 00	3,200 00		
Assistant Professor	2,700 00	2,700 00		
Instructor	2,300 00	2,300 00		
Laboratory Assistant	1,200 00	1,200 00		
Photographer	1,900 00	1,900 00		
Caretaker	1,300 00	1,300 00		
Department of Physical Training:				
Director	6,000 00	6,000 00		
Assistant Director	2,800 00	2,800 00		
Coach	2,000 00	2,000 00		
Instructor	2,200 00	2,200 00		
Instructor	2,500 00	2,500 00		
Instructor	1,800 00	1,800 00		
Instructor	1,800 00	1,800 00		
Instructor	2,100 00	2,100 00		
Department of Zoology:				
Professor	4,250 00	(a) 4,250 00		
Associate Professor	3,200 00	3,200 00		
Associate Professor	3,200 00	3,200 00		
Instructor	2,500 00	2,500 00		
Instructor	2,400 00	2,400 00		
DIVISION OF VETERINARY SCIENCE.				
Department of Anatomy:				
Acting Dean	4,200 00	4,200 00		
Assistant Professor	3,000 00	3,000 00		
Assistant Professor	2,800 00	2,800 00		
Stenographer	1,300 00	1,300 00		
Department of Pathology:				
Associate Professor	4,000 00	2,000 00	2,000 00	
Assistant Professor	2,600 00	2,600 00		

TABLE NO. 11—*Continued.*

	Rate per year.	Classification.		Extension.
		Current.	Experiment Station.	
Department of Surgery and Medicine:				
Associate Professor	$3,800 00	$3,800 00		
Assistant Professor	2,600 00	2,600 00		
DIVISION OF AGRICULTURE.				
Dean	5,500 00	(a) 2,750 00	$2,750 00	
Clerk	1,600 00	800 00	800 00	
Department of Animal Husbandry:				
Professor	4,250 00	2,850 00	1,400 00	
Assistant Professor	2,800 00	2,100 00	700 00	
Herdsman	1,800 00	(a) 1,800 00		
Stenographer	675 00	675 00		
Department of Dairy Husbandry:				
Professor	5,500 00	4,500 00	1,000 00	
Associate Professor	3,200 00	2,800 00	400 00	
Associate Professor	3,000 00	2,000 00	1,000 00	
Superintendent Advanced Registry	2,000 00	2,000 00		
Clerk	1,350 00	675 00	675 00	
Clerk	1,200 00	1,200 00		
Research Assistant	2,400 00		2,400 00	
Department of Farm Crops:				
Professor	5,000 00	3,500 00	1,500 00	
Associate Professor	4,200 00	1,200 00	3,000 00	
Assistant Professor	3,100 00	2,350 00	750 00	
Assistant Professor	3,200 00	1,000 00		$2,200 00
Assistant Professor	2,400 00	2,200 00	200 00	
Graduate Assistant	800 00	800 00		
Assistant in Farm Crops	2,300 00		750 00	1,550 00
Assistant in Farm Crops	2,400 00		2,400 00	
Instructor	2,200 00	1,500 00	700 00	
Instructor	2,500 00	700 00	1,800 00	
Stenographer	1,300 00	650 00	650 00	
Department of Farm Mechanics:				
Professor	4,500 00	3,600 00	900 00	
Assistant Professor	2,600 00	1,300 00	1,300 00	
Assistant Professor	2,600 00	1,400 00	1,200 00	
Instructor	1,800 00	1,800 00		
Instructor	1,600 00	1,600 00		
Stenographer	675 00	675 00		
Department of Farm and Horses:				
Superintendent	3,000 00	3,000 00		
Department of Poultry:				
Associate Professor	3,200 00	2,400 00	800 00	
Instructor	1,800 00	1,800 00		
Foreman	1,600 00	1,600 00		
Stenographer	1,200 00	1,200 00		
Department of Forestry:				
Professor	5,000 00	4,000 00	1,000 00	
Assistant Professor	2,700 00	2,700 00		
Instructor	2,000 00	2,000 00		
Foreman	1,900 00	1,900 00		
Stenographer	1,350 00	1,350 00		
Department of Horticulture:				
Professor	4,500 00	3,000 00	1,500 00	
Associate Professor	3,500 00	3,100 00	400 00	
Assistant Professor	2,600 00	2,100 00	500 00	
Assistant Professor	2,400 00	(a) 2,400 00		
Assistant Professor	2,750 00	700 00	2,050 00	
Instructor	300 00	300 00		
Stenographer	1,350 00	675 00	675 00	
Assistant in Horticulture	3,500 00		900 00	2,600 00
Research Assistant	3,000 00		3,000 00	
Assistant	1,500 00		1,500 00	

TABLE NO. 11—*Continued.*

	Rate per year.	Classification.		Extension.
		Current.	Experiment Station.	
Department of Soils:				
Professor	$5,000 00	$2,500 00	$2,500 00	
Associate Professor	1,800 00	1,800 00		
Assistant Professor	3,200 00	800 00	1,600 00	$800 00
Assistant Professor	2,600 00	1,700 00	900 00	
Instructor	2,000 00	1,400 00	600 00	
Research Associate	3,200 00		3,200 00	
Research Associate	3,800 00		3,800 00	
Research Associate	3,400 00		2,200 00	1,200 00
Research Associate	1,600 00		1,600 00	
Research Assistant	3,000 00		3,000 00	675 00
Stenographer	1,350 00		675 00	
Special Courses:				
Director	3,200 00	1,700 00	1,500 00	
Instructor	2,000 00	800 00	1,200 00	
Experiment Station Chemistry:				
Chemist	4,500 00		4,500 00	
Research Associate	3,200 00		3,200 00	
Research Associate	2,800 00		2,800 00	
Research Assistant	3,800 00		3,800 00	
Assistant	1,800 00		1,800 00	
Bulletin Clerk	1,350 00		1,350 00	
DIVISION OF EXTENSION.				
Administration:				
Director	4,500 00			4,500 00
Assistant Director	2,800 00			2,800 00
Clerk	1,400 00			1,400 00
Stenographer	1,200 00			1,200 00
County Agents:				
Assistant	3,300 00			3,300 00
Assistant	3,000 00			3,000 00
Stenographer	600 00			600 00
Stenographer	650 00			650 00
Agent, Alger County	1,200 00			1,200 00
Agent, Allegan County	1,200 00			1,200 00
Agent, Alpena County	1,200 00			1,200 00
Agent, Antrim County	1,500 00			1,500 00
Agent, Baraga County	1,200 00			1,200 00
Agent, Barry County	1,200 00			1,200 00
Agent, Benzie County	1,200 00			1,200 00
Agent, Berrien County	1,200 00			1,200 00
Agent, Branch County	1,200 00			1,200 00
Agent, Calhoun County	1,200 00			1,200 00
Agent, Cass County	1,200 00			1,200 00
Agent, Charlevoix County	1,200 00			1,200 00
Agent, Cheboygan County	1,200 00			1,200 00
Agent, Crawford County	1,200 00			1,200 00
Agent, Clinton County	1,200 00			1,200 00
Agent, Dickinson County	1,200 00			1,200 00
Agent, Eaton County	1,200 00			1,200 00
Agent, Emmet County	1,200 00			1,200 00
Agent, Genesee County	1,200 00			1,200 00
Agent, Gladwin County	1,200 00			1,200 00
Agent, Gratiot County	1,200 00			1,200 00
Agent, Gogebic County	1,200 00			1,200 00
Agent, Houghton County	1,200 00			1,200 00
Agent, Hillsdale County	1,200 00			1,200 00
Agent, Huron County	1,200 00			1,200 00
Agent, Iron County	1,200 00			1,200 00
Agent, Ionia County	1,200 00			1,200 00
Agent, Kalamazoo County	1,200 00			1,200 00
Agent, Jackson County	1,200 00			1,200 00
Agent, Kent County	1,200 00			1,200 00
Agent, Lapeer County	1,200 00			1,200 00
Agent, Leelanau County	1,200 00			1,200 00
Agent, Lenawee County	1,200 00			1,200 00
Agent, Livingston County	1,200 00			1,200 00
Agent, Luce County	1,200 00			1,200 00
Agent, Macomb County	1,200 00			1,200 00

TABLE NO. 11—*Continued.*

	Rate per year.	Classification.		Extension.
		Current.	Experiment Station.	
County Agents—*Continued.*				
Agent, Manistee County	$1,200 00			$1,200 00
Agent, Marquette County	1,200 00			1,200 00
Agent, Mason County	1,200 00			1,200 00
Agent, Mecosta County	1,200 00			1,200 00
Agent, Menominee County	1,200 00			1,200 00
Agent, Midland County	1,200 00			1,200 00
Agent, Missaukee County	1,200 00			1,200 00
Agent, Montcalm County	1,200 00			1,200 00
Agent, Muskegon County	1,200 00			1,200 00
Agent, Newaygo County	1,200 00			1,200 00
Agent, Ogemaw County	1,200 00			1,200 00
Agent, Otsego County	1,200 00			1,200 00
Agent, Ottawa County	1,200 00			1,200 00
Agent, Oakland County	1,200 00			1,200 00
Agent, Oceana County	1,200 00			1,200 00
Agent, Ontonagon County	1,200 00			1,200 00
Agent, Osceola County	1,800 00			1,800 00
Agent, Presque Isle	1,200 00			1,200 00
Agent, Sanilac County	1,200 00			1,200 00
Agent, Saginaw County	1,200 00			1,200 00
Agent, Schoolcraft County	1,200 00			1,200 00
Agent, Shiawassee County	1,200 00			1,200 00
Agent, St. Clair County	1,200 00			1,200 00
Agent, St. Joseph County	1,200 00			1,200 00
Agent, Tuscola County	1,200 00			1,200 00
Agent, Van Buren County	1,200 00			1,200 00
Agent, Washtenaw County	1,200 00			1,200 00
Agent, Wayne County	1,200 00			1,200 00
Agent, Wexford County	1,200 00			1,200 00
Home Demonstration Agents:				
Agent, Dickinson County	2,000 00			2,000 00
Agent, Kalamazoo County	1,000 00			1,000 00
Agent, Allegan County	1,000 00			1,000 00
Agent, Wayne County	1,000 00			1,000 00
Agent, Oakland County	1,000 00			1,000 00
Agent, Gladwin County	1,000 00			1,000 00
Agent, Ottawa County	400 00			400 00
Agent, Marquette County	1,000 00			1,000 00
Agent, Gogebic County	1,000 00			1,000 00
Stenographer	600 00			600 00
Boys' and Girls' Club:				
Agent, Branch County	600 00			600 00
Agent, Calhoun County	600 00			600 00
Agent, Cheboygan County	600 00			600 00
Agent, Genesee County	600 00			600 00
Agent, Hillsdale County	600 00			600 00
Agent, Iron County	600 00			600 00
Agent, Lenawee County	600 00			600 00
Agent, Macomb County	600 00			600 00
Agent, Monroe County	600 00			600 00
Agent, Van Buren County	600 00			600 00
Agent, Wayne County	600 00			600 00
Agent, Washtenaw County	600 00			600 00
Home Economics:				
State Leader	2,000 00			2,000 00
Specialist	3,000 00			3,000 00
Specialist	3,000 00			3,000 00
Specialist	3,000 00			3,000 00
Stenographer	1,200 00			1,200 00
Boys' and Girls' Club Work:				
State Leader	2,120 00			2,120 00
District Leader	1,520 00			1,520 00
Specialist	2,460 00			2,460 00
Assistant	2,500 00			2,500 00
Specialist	2,600 00			2,600 00
Assistant	2,200 00			2,200 00
Stenographer	1,200 00			1,200 00

TABLE NO. 11—*Concluded.*

	Rate per year.	Classification.		Extension.
		Current.	Experiment Station.	
Farm Crops:				
Specialist	$3,100 00			$3,100 00
Specialist	1,800 00			1,800 00
Stenographer	1,300 00			1,300 00
Live Stock:				
Specialist	3,000 00			3,000 00
Specialist	3,200 00			3,200 00
Specialist	3,100 00			3,100 00
Horticulture:				
Stenographer	600 00			600 00
Potatoes and Vegetables:				
Specialist	3,600 00			3,600 00
Specialist	2,750 00			2,750 00
Stenographer	600 00			600 00
Farm Manegament Demonstration:				
Demonstrator	2,000 00			2,000 00
Specialist	2,000 00			2,000 00
Specialist	2,000 00			2,000 00
Household Engineering and Drainage:				
Specialist	3,200 00			3,200 00
Markets:				
Assistant Extension Director	6,000 00			6,000 00
Specialist	4,000 00			4,000 00
Field Agent	3,500 00			3,500 00
Stenographer	1,200 00			1,200 00
Poultry:				
Specialist	2,500 00			2,500 00
Lecturer:				
Specialist	4,000 00			4,000 00
Land Clearing:				
Specialist	3,600 00			3,600 00
Vocational Teacher Training:				
Professor	3,500 00			3,500 00
Associate Professor	3,200 00			3,200 00
Assistant Professor	3,200 00			3,200 00
Assistant Professor	2,800 00			2,800 00
Instructor	1,550 00			1,550 00
Stenographer	1,350 00			1,350 00
Totals	$954,025 00	$592,775 00	$132,175 00	$210,975 00 V.$18,100 00

a House in addition.
b Room in addition.

TABLE NO. 12.—*Income of the Michigan Agricultural College from all outside sources from the date of its foundation to the present time.*

Year.	From State Legislature.			From U. S. Congress.				Total.
	For current expenses.	For special purposes.	Land sales, salt spring and swamp land grants.	Morrill act, of 1862, interest from land grant and trespass.	Hatch act of 1887, and Adams act of 1906, experiment station.	Morrill act of 1890, supplementary endowment.	Smith Lever act of 1914, extension.	
1855			$56,320 00					$56,320 00
1856								
1857	$40,000 00							40,000 00
1858								
1859	37,500 00							37,500 00
1860								
1861	6,500 00		152 25					6,652 25
1862	10,000 00		218 97					10,218 97
1863	9,000 00		407 80					9,407 80
1864	9,000 00		726 09					9,726 09
1865	15,000 00		1,156 61					16,156 61
1866	15,000 00		1,094 27					16,094 27
1867	20,000 00		7,608 38					27,608 38
1868	20,000 00		592 49					20,592 49
1869	20,000 00	$30,000 00	17,559 00	$58 96				67,617 96
1870	20,000 00		1,320 02	2,720 93				24,010 95
1871	18,250 00	10,500 00	4,135 72	3,785 54				36,671 26
1872	18,250 00	3,000 00	217 05	7,175 65				28,642 70
1873	21,796 00	15,602 00	10 13	11,059 06				48,467 19
1874	13,000 00	15,602 00	150 13	14,061 98				42,814 11
1875	7,638 00	7,755 50	144 53	14,446 14				29,984 17
1876	7,638 00	6,755 50	1,773 09	16,830 17				32,996 76
1877	6,150 00	30,686 80	979 06	15,172 86				52,988 72
1878	6,150 00	5,686 80	826 60	15,807 09				28,470 49
1879	4,971 80	16,068 32	712 22	16;978 22				38,730 56
1880	4,971 80	7,068 32	797 55	17,837 24				30,674 91
1881	7,249 00	43,720 50	461 95	20,935 25				72,366 70
1882	7,249 00	8,945 50	358 46	22,507 45				39,060 41
1883	8,385 00	23,793 00	391 95	30,749 60				63,319 52
1884	8,385 00	10,526 00	1,259 90	27,909 72				48,080 65

1885		35,103 00	187 50	29,770 40				65,060 90
1886		22,617 00		30,461 04				53,078 04
1887		*44,040 00	198 20	†24,611 37				68,849 57
1888		30,752 50	144 20	32,406 60	15,000 00			78,303 30
1889		*20,973 00	10 50	31,322 69	15,000 00			67,306 19
1890		*27,172 00	238 50	32,360 64	15,000 00	15,000 00		89,771 14
1891		22,947 50	37 38	34,750 54	15,000 00	16,000 00		88,735 42
1892		22,947 50	137 38	34,948 12	15,000 00	17,000 00		90,033 00
1893		18,862 50	10 50	37,927 04	15,000 00	18,000 00		89,800 04
1894		18,862 50	433 59	44,527 26	15,000 00	19,000 00		97,823 35
1895		‡19,000 00	10 50	45,301 85	15,000 00	20,000 00		99,312 35
1896		‡16,000 00		43,886 40	15,000 00	21,000 00		95,886 40
1897		§17,700 00		43,779 54	15,000 00	22,000 00		98,479 54
1898		‖17,500 00		47,508 28	15,000 00	23,000 00		103,008 28
1899		¶8,750 00	705 00	52,526 11	15,000 00	24,000 00		100,981 11
1900		¶72,500 00	175 00	72,298 38	15,000 00	25,000 00		184,973 38
1901††		¶72,500 00		63,976 79	15,000 00	25,000 00		176,476 79
1902	100,000 00	**1,000 00		64,081 81	15,000 00	25,000 00		205,081 81
1903	100,000 00	**1,000 00		65,573 90	15,000 00	25,000 00		206,573 90
1904	100,000 00	**1,000 00	61 19	67,312 37	15,000 00	25,000 00		208,373 56
1905	100,000 00	*81,000 00		72,035 32	15,000 00	25,000 00		293,035 32
1906	157,810 00	*15,000 00		70,286 56	15,000 00	25,000 00		283,096 56
1907	173,410 00	**1,000 00		70,155 22	23,691 60	25,000 00		293,256 82
1908	173,410 00	**1,000 00		70,385 79	23,326 10	30,000 00		298,121 89
1909	173,410 00	**1,000 00		69,527 13	26,000 00	35,000 00		304,937 13
1910	173,410 00	**1,000 00		71,109 49	28,000 00	40,000 00		313,519 49
1911	173,410 00	**1,000 00		70,304 15	30,000 00	45,000 00		319,714 15
1912	228,800 00	**1,000 00		70,265 32	30,000 00	50,000 00		380,065 32
1913	228,800 00	**1,000 00		70,289 30	30,000 00	50,000 00		380,089 30
1914	228,800 00	**1,000 00		71,324 94	30,000 00	50,000 00		381,124 94
1915	308,147 25	**1,000 00		70,385 46	30,000 00	50,000 00	10,000 00	469,532 71
1916	560,000 00	**1,000 00		71,391 56	30,000 00	50,000 00	28,032 37	740,423 93
1917	560,000 00	**1,000 00		69,437 43	30,000 00	50,000 00	43,059 35	753,496 78
1918	560,000 00	**1,000 00		70,502 10	30,000 00	50,000 00	58,086 33	769,588 43
1919	560,000 00	**1,000 00		70,662 44	30,000 00	50,000 00	73,113 31	784,775 75
1920	900,000 00	***35,000 00		70,736 34	30,000 00	50,000 00	133,221 23	1,218,957 57
1921	900,000 00	***35,000 00		70,685 37	30,000 00	50,000 00	148,172 80	1,233,858 17
1922	1,000,000 00	70,000 00		70,838 32	30,000 00	50,000 00	151,585 39	1,372,423 71
Totals	$7,821,490 85	$975,937 74	$101,723 66	$2,407,689 23	$746,017 70	$1,095,000 00	$645,270 78	$13,793,129 96

*Including appropriation for weather service.
†October 1, 1886, to June 30, 1887, nine months.
‡Including $5,000 for institutes and $1,000 for weather service.
‖Including $5,500 for institutes and $1,000 for weather service.
§Including $2,750 for institutes and $500 for weather service.
††To June 30.
**Weather service.
¶ Including $5,500 for institutes and $1,000 for weather service.
***Extension.

SUMMARY OF COLLEGE INVENTORY, JUNE 30, 1922.

Buildings and Lands:	
College farm and park, 671 acres	$67,100 00
Lots 2, 3 and 4, River Bend addition	4,000 00
Athletic field and drive, 13 acres	1,300 00
320 acres swamp land	960 00
Purchased C. D. Woodbury farm, 1916, 308.82 acres	38,602 50
1 acre more or less formerly belonging to Harrison, adjacent to campus	2,000 00
Purchased in 1913, 27 acres	3,375 00
50,359 acres, remainder of land grant not formerly carried in inventory	251,795 00
Buildings:	
Library and museum, built 1881	22,000 00
Wells Hall, rebuilt 1905-06	55,000 00
Abbot Hall, built 1888, addition in 1896	15,000 00
Chemical laboratory, built in 1871, south end addition in 1881, east end addition in 1911	35,000 00
Veterinary laboratory, built in 1885	5,000 00
Horticultural laboratory, built 1888	7,000 00
Entomological laboratory, built 1889, improved 1897	7,500 00
Botanical laboratory, built 1892, improved 1909	20,000 00
Armory, built 1885	6,000 00
Greenhouse and stable, built 1873, 1879, rebuilt 1892 and 1902	6,000 00
President's and two frame dwellings, built 1874	12,000 00
Six brick dwellings, built 1857, 1879 and 1884	18,000 00
One frame house, built 1885	3,500 00
Howard Terrace dwelling, built 1888	13,000 00
Farm house dwelling, built 1869	2,000 00
Bull barn, rebuilt 1905	1,500 00
Sheep barn, rebuilt 1906	2,500 00
Horse barn, built 1906	5,000 00
Grade herd barn, rebuilt 1905	4,000 00
Piggery, rebuilt 1907	1,500 00
Dairy barn, rebuilt 1900	4,000 00
Poultry house, built 1906	1,000 00
Incubator house, built 1906	500 00
Poultry house, built 1907	1,500 00
Three poultry houses, built 1907	300 00
Ten brooder houses, built 1908	250 00
Corn barn, built 1878	400 00
Observatory, built 1880	100 00
Bath house and fittings, built 1902-3	17,000 00
Hospital built 1894	3,000 00
Waiting room and book store, built 1902	1,700 00
One silo	200 00
Women's building, built 1909	91,000 00
Forestry building, built 1900	15,000 00
Bacteriological building, built 1902	27,000 00
Power house, built 1904	25,000 00
Tunnel system, built 1904	45,000 00
Cold storage, rebuilt 1905	2,000 00
Iron bridge over Cedar river, built 1888	1,500 00
Bridge to athletic field	500 00
Manure shed	600 00
Four hospital cottages, built 1909	6,000 00
Agricultural building, built 1909	182,000 00
Tile silo, No. 1	500 00
Piggery for serum production	1,000 00
Two tenant dwellings, built 1912	2,400 00
New dairy building, built 1913	55,000 00
Tile silo, No. 2	600 00
Tile silo, No. 3	600 00
2 cement stave silos	800 00
Forestry packing house	1,000 00
Veterinary laboratory, 1914	33,000 00
Special chemical laboratory	800 00
R. E. Olds Hall of Engineering, built 1916	155,000 00
Shop No. 1, built 1916	26,400 00
Shop No. 2, built 1916	15,750 00
Shop No. 3, built 1916	14,500 00
Gymnasium, built 1916	220,000 00
Shop and storehouse, built 1919-1920	34,000 00
Boiler house, built 1921	153,000 00
Coal pit, built 1921	900 00
Entomological Laboratory, built 1921	3,400 00
Addition to poultry house	1,800 00
	$1,756,632 50

SUMMARY OF COLLEGE INVENTORY, June 30, 1922—*Continued.*

Amount forwarded	$1,756,632 50
Division of Agriculture:	
Department of Agricultural Education	$630 25
Department of Animal Husbandry	22,237 65
Department of Dairy Husbandry	48,344 61
Office of Dean of Agriculture	1,245 21
Department of Farm Crops	3,797 12
Department of Farm and Horses	30,154 19
Department of Farm Management	550 86
Department of Farm Mechanics	7,165 73
Department of Forestry	21,148 20
Department of Horticulture	6,207 87
Department of Poultry Husbandry	10,898 19
Department of Soils	9,122 15
Division of Applied Science:	
Department of Bacteriology	19,557 09
Department of Botany	28,572 94
Department of Chemistry	68,369 28
Department of Entomology	12,378 66
Department of Meteorology	263 27
Department of Physiology and Zoology	33,874 21
Department of Physics	14,010 48
Division of Engineering:	
Department of Civil Engineering	21,478 35
Department of Drawing and Design	10,123 98
Department of Electrical Engineering	26,497 59
Department of Mechanical Engineering	87,744 22
Office of Dean of Engineering	2,924 37
Division of Experiment Station:	
Section of Buildings and Lands	88,175 00
Section of Bacteriology	13,477 99
Section of Botany	8,033 72
Bulletin Room	2,575 21
Section of Chemistry	14,932 58
Office of the Director	637 12
Section of Entomology	8,747 43
Section of Farm Crops	2,177 45
Section of Farm Management	1,290 24
Section of Graham Horticultural Station	4,118 40
Section of Horticulture	2,026 05
Section of Library	10,202 90
Section of Soils	6,243 49
Section of South Haven Experiment Station	1,970 09
Section of Upper Peninsula Experiment Station	20,199 52
Division of Extension:	12,836 62
Division of Home Economics	31,085 93
Division of Letters:	
Department of Economics	294 40
Department of English	1,440 69
Department of History and Political Science	1,002 15
Department of Mathematics	865 50
Department of Military Science	9,917 53
Department of Music	2,435 00
Department of Physical Training	15,550 30
Division of Veterinary Science:	
Department of Anatomy	21,327 56
Dean's Office	2,406 96
Department of Pathology	7,530 19
Department of Surgery and Medicine	4,164 43
Miscellaneous:	
Alumni Recorder	1,025 89
Carpenter Shop	5,873 10
Fire Department	9,389 55
Health Service	5,768 58
Library	84,616 36
Paint Shop	717 33
Post Office	1,383 21
Office of President	1,500 98
Office of Purchasing Agent	686 71
Office of Registrar	1,558 40
Office of Secretary	5,611 21
Store	43,822 95
Vocational Teacher Training	690 37
Water, heat and light	109,379 33
Total	$2,811,147 39

REPORT OF THE DEAN OF AGRICULTURE.

To President David Friday:

In the educational work of the Agricultural Division this year witnessed a marked return to normal over the conditions prevailing during some of the recent years on account of war conditions. The total enrollment in the regular four year course including graduate students was eight hundred and thirty-nine an increase of one hundred and two over the previous year. The attendance in the various short courses was slightly smaller than last year. The following statistics present a classified statement of the enrollment within the division during the year.

Advanced Degree	11	
Graduate Students	13	
Graduating Class	104	
Seniors	111	
Juniors	128	
Sophomores	121	
Freshmen	187	
Specials	4	
Summer Session	160	
		839
Sixteen Weeks' Course in General Agriculture first year	75	
Sixteen Weeks' Course in General Agriculture second year	25	
Eight Weeks' Course in General Agriculture first year	35	
Eight Weeks' Course in General Agriculture second year	13	
Eight Weeks' Course in Horticulture	35	
Eight Weeks' Course in Farm Engineering	7	
Eight Weeks' Course in Dairy Production	32	
Eight Weeks' Course in Dairy Manufacture	32	
Eight Weeks' Course in Farm Business	5	
Four Weeks' Course in Poultry Husbandry	24	
Four Weeks' Course in Ice Cream Making	21	
Two Weeks' Course in Cow Testing and Dairy Barn Management	50	
First Truck and Tractor Course	20	
Second Truck and Tractor Course	26	
Third Truck and Tractor Course	26	
Fourth Truck and Tractor Course	22	
Special Courses	6	
		454
Total		1293

The usual number of farmers' and stockmen's meetings were held during the year. Most notable among these were the meetings of the State

Live Stock Breeders' and Feeders' Association in January, the Farmer's Week in February and Farmer's Day the previous August. All three of these were unprecedented successes. Farmers' Week originally an Agricultural Division undertaking has become an institutional affair. in which all divisions of the institution participate heartily and harmoniously.

During this year the Division again entered competitions with dairy and stock judging teams at National and International Expositions, making creditable winnings. The Animal Husbandry Department achieved the signal honor of winning grand championship on steer carcass at the 1921 International Live Stock Exposition.

The Division is pursuing its past policy of trying to build up and maintain uniformly strong and efficient departments. The Horticultural Department is badly in need of a new building providing offices and laboratories together with commercial greenhouses. A new farm mechanics building with equipment is also sorely needed as this phase of educational work is becoming more and more important to the farmer. The removal of some old buildings formerly used has greatly restricted the usable space.

In addition to the 1020 acres of land now owned by the College at East Lansing, an additional 200 acres to the south has been rented with option of purchase. While this additional land is now needed, future years will certainly justify the contemplated purchase in the very near future.

It is gratifying to be able to report relationships of harmony and enthusiastic effort throughout the entire Division.

Respectfully submitted,
R. S. SHAW,
Dean of Agriculture.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF ANIMAL HUSBANDRY.

President David Friday,
College.

Dear Sir:

I have the honor to submit the following report of the Department of Animal Husbandry for the year ending June 30, 1922.

The following table gives a summary of the teaching work carried by the staff the past year:

Subject.	Sect.	Days per week.	Hours per week.	No. in class.	Instructor.
Fall Term:					
Regulars.					
A. H. 1	1–4	3	5	64	W. E. J. Edwards
A. H. 1	5–8	3	5	56	G. A. Brown
A. H. 1	9–12	3	5	65	W. E. J. Edwards
A. H. 2		3	5	55	W. E. J. Edwards
A. H. 5		5	8	32	G. A. Brown
Short Course.					
A. H. 1		5	10	61	H. E. Dennison and W. E. J. Edwards
A. H. 4b		5	5	61	G. A. Brown
Winter Term:					
Regulars.					
A. H. 6	1	5	8	9	G. A. Brown
A. H. 6	2	5	8	12	G. A. Brown
Short Course.					
Study of Types		5	10	31	H. E. Dennison and W. E. J. Edwards
Study of Breeds		4	8	51	W. E. J. Edwards
Stock Judging		5	10	30	R. L. Mackie
Live Stock Management		3	3	28	W. E. J. Edwards
Feeding		5	5	30	G. A. Brown
Spring Term:					
Regulars.					
A. H. 4b		3	3	39	G. A. Brown
A. H. 7		5	8	21	G. A. Brown
Federal.					
A. H. 1		3	6	48	W. E. J. Edwards

As shown by the above outline the schedule of teaching work has been extremely heavy and has consumed the major portion of the time of the two members of the department. The freshmen classes should, in justice to both students and instructor, be divided into smaller sections for the laboratory work. The same is true of some of the short course classes. I earnestly request that the personnel of the department be increased to a point where classes can be divided into sections of not over thirty men for laboratory work. The large amount of classroom work during the fall and winter terms, prevents the members of the department assisting in extension work or attending live stock breeders' meetings in different parts of the State.

EXTENSION.

Mr. Donald Williams who has been doing extension work in sheep husbandry for three years, was released March 1 to take charge of the Farm Bureau Wool Pool, resulting in a temporary break in this service for which there is an urgent demand. Mr. Verne Freeman is taking up extension work with the department, July 1. Mr. Freeman will devote his time to work with the beef cattle and swine interests of the State. Not less than three men should be employed to carry on the extension work with beef cattle, sheep and swine.

Mr. W. E. J. Edwards devoted a considerable part of April and May to extension work, holding 30 meetings in seven counties, which were attended by 1050 farmers.

JUDGING FAIRS.

During August and September, 1921, the members of the department acted as Official Judges of live stock at 26 county fairs and also at the

State Fair. This work keeps the College in close touch with the live stock breeders of the State and furnishes the department an opportunity to extend its teachings of correct type and form, which must be associated with efficient production in animals, to a larger number of farmers than can be reached in any other way.

LIVE STOCK EQUIPMENT.

The following represents the live-stock equipment at present:

Beef Cattle	
Herefords	27
Aberdeen Angus	22
Shorthorn	26
Total	75
Sheep	
Southdown	24
Shropshire	43
Hampshire	52
Oxford	44
Cotswold	16
Rambouillet	50
Dorsets	10
Total	239
Swine	
Duroc Jersey	45
Poland China	34
Chester White	34
Berkshire	37
Tamworth	39
Yorkshire	32
Hampshire	10
Total	231

The above numbers include the spring calves, lambs and pigs, many of which are now on experimental feeding test and will be disposed of early this fall.

Practically no funds have been available for the purchase of better live stock for several years. The Hereford and Shorthorn cattle at present are not of as high a standard of excellence as should be maintained by the College, and better representatives of these breeds should be obtained as soon as possible.

The Aberdeen Angus herd was very materially strengthened when Mr. W. E. Scripps of Detroit presented the College with an Aberdeen Angus herd bull "Plumb Square and Level," a superior individual sired by the noted bull, Edgar of Dalmeny, which Mr. Scripps imported from Scotland for use on his Wildwood Farm at Orion, Michigan.

Plumb Square and Level was:

1st Prize Calf and Junior Champion Bull at the Michigan State Fair in 1920.
2nd Prize Yearling at the State Fair in 1921, and
4th Prize Yearling Bull at the 1921 International:

The limited area of land surrounding the present piggery and the crowded conditions, have prevented the development of high class individuals. With the completion of the new plant now under consideration, a superior male and female of each of the several breeds represented in the herd, should be purchased.

By the purchase of better sires than have been used in the past, the sheep flock would in a short time be of superior excellence.

For several years the appropriation for the department has been barely sufficient to maintain the equipment, making it necessary to pursue a policy of rigid economy in all purchases, whereas we should be able to purchase only the best, especially of sires, in order to have superior individuals for classroom work.

LIVE STOCK EXHIBITS.

An exhibit of beef cattle was made at the State Fair in 1921. Our winnings being as follows: 1st Prize Steer Herd, 2nd Prize Two-year Old Steer, 2nd Prize Steer Calf, 3rd Prize Yearling Steer, 4th Prize Aberdeen Angus Bull and 4th Prize Senior Aberdeen Angus Calf.

For the first time since 1901 an exhibit of 9 steers, 15 sheep and 1 hog was made at the 1921 International Live Stock Exposition, winning 14 prizes which includes three First Prizes and one Championship. All of the live stock exhibited was bred and fitted at the College. The Aberdeen Angus Steer, College Erin, furnished the First Prize Junior Yearling Carcass and the Grand Championship Carcass of the show—a much coveted honor.

BUILDINGS.

A new piggery which is sadly needed is now being planned and will be constructed this fall.

The beef cattle and sheep barns are both inadequate for the work which we should be doing at the present time. The sheep barn should be enlarged to give room for experimental work in sheep feeding, and placed in a location where the sheep would have access to grazing plots rather than being closely confined as they are at the present time.

The beef barn is not large enough for the fitting of show herds and the management of the breeding herd at the same time. It would have to be remodeled to give good facilities for fitting show herds, and should be enlarged to give room for experimental steer feeding. To do this properly would necessitate the erection of a new building for which we have urgent need at the present time. Such a building should be located across the river where more room would be available.

ACKNOWLEDGMENTS.

I desire to express my sincere appreciation of the assistance which Mr. Edwards has given in instruction work, Mr. Mackie in managing the herds and flocks, and Mr. Walker in fitting show cattle.

Respectfully submitted,
GEO. A. BROWN,
Professor of Animal Husbandry.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF DAIRY HUSBANDRY.

President David Friday,
Michigan Agricultural College.

Dear Sir:

I herewith submit the report of the work of the Department of Dairy Husbandry for the year ending June 30, 1922.

The personnel of the department has been as follows:

O. E. Reed, Professor of Dairy Husbandry.
J. E. Burnett, Associate Professor of Dairy Husbandry.
O. T. Goodwin, Associate Professor of Dairy Manufactures.
H. E. Dennison, Assistant Professor of Dairy Husbandry.
Transferred to Extension Dept., Jan. 1, 1922.
C. E. Newlander, Assistant Professor of Dairy Manufactures.
Resigned Jan. 1, 1922.
Hilda Kellner, Instructor in Dairy Manufactures.
Resigned, September 1, 1921.
E. B. Hint, Superintendent of Official Testing.
Stanley J. Brownell, Research Assistant in Dairying.
H. C. Jordan, Instructor in Cheese Making.
January 1st—March 1st, 1922.

INVESTIGATION AND TEACHING.

Investigation in this department for the past year has been somewhat neglected on account of the shortage of help, as well as the necessity of spending a great deal of time in the extension field. Mr. Stanley J. Brownell, Research Assistant in Dairying, has published the bulletin "Studies in Milk Distribution." Other work conducted has been the studies with sweet clover as a pasture for dairy cattle. The first trial was in June and July, 1921, and the results were reported in the Quarterly Bulletin. The breeding experiments conducted in co-operation with the U. S. Department of Agriculture have been continued and are still being carried on. Minor investigations in the study of the production of clean milk have also been started in co-operation with the Bacteriology Department.

On account of the establishment of new courses during the past year the teaching work of this department has increased materially. A total of 926 students received instruction throughout the year. This includes instruction in both long and short courses. There were 357 regular college students and 569 short course students.

In January of this year the department offered a course for the field men of the creamery manufacturing and milk distributing plants, and this course was attended by 50 of these representatives. We feel that this sort of instruction given in this type of course, is very beneficial to the institution. These field men come in direct contact with the farmer and by giving them instruction as to proper methods of feeding and caring for cattle and handling milk, we are able to see that the farmer gets the right kind of instruction from these men. It is planned to continue such courses in the future.

A number of short courses were given, including a two weeks' course in testing for men desiring to conduct official testing. This course attracted 50 students.

A two week's course was given for ice cream manufacturers during the month of March, which was attended by 22 students.

The College was represented last year by a students' judging team at the National Dairy Show. This contest created a great deal of interest among the students and the team which was composed of four men met in competition with 16 other agricultural colleges and succeeded in winning third place.

During the past year the M. A. C. creamery has been put upon a commercial basis. This has been done in order to give our students instruction in a commercial concern. This is highly important, particularly for the training of our short course students who are here for only a very short time. They will not only get instruction as to methods of making butter and handling other milk products, but have opportunity to study business methods and the operation of a creamery. The plan that has been adopted is to operate this creamery on a commercial basis and maintain the output at the maximum of 25,000 pounds of butter per month. The creamery was placed on this basis October 17, 1921. At that time the total production of butter was 5,000 pounds and this has steadily increased until in June the production was 20,000 pounds.

The dairy herd has been increased considerably during the past year. A large number of official records have been completed and the herd has thereby been increased in value to a marked degree. The records that are worthy of note are: Colantha Mutual Queen No. 256679 for 365 days, 24174.2 pounds of milk and 1026.7 pounds of butter. Pauline Colantha Fayne No. 460895 for 365 days, 19662.1 pounds of milk and 737.7 pounds of butter. That was the State Junior two year old milk record for the breed when it was made.

During the past year improvements and additions have been made at the dairy barn so as to produce and care for milk of high quality. The object in establishing this sort of business is to enable the department to give the best possible instruction in the care of milk on the farm that is to be used for human consumption, and thereby stimulate the interest in the production of clean, wholesome milk in the small towns and cities of the State. This milk, produced at the barn, is regularly inspected and analyzed by the Bacteriology Department. The quality of the milk thus far produced has been exceptionally good, and the whole project has been very gratifying.

The department made an exhibit at the State Fair, Detroit, and also in conjunction with the Allied Dairy Association at Saginaw during the year. These exhibits were planned to show the type of work being done at the College and they also embodied the lessons of efficient and economical production.

EXTENSION SERVICE.

A great deal of time has been spent by the members of this department in administering and conducting the dairy extension work during the past year. Mr. J. A. Waldron has continued in charge of extension work and Mr. A. C. Baltzer has been assisting in this work throughout the year. Mr. H. E. Dennison was added to the Extension staff on January 1st. In addition to these men other members of the department have spent a liberal amount of time doing field work. New methods have been worked out in the conduct of extension work during the past year. County campaigns have been arranged and carried out in eight counties. This method of getting the information to the farmer has been found the most effective of any yet devised. The plan in brief is to spend a sufficient length of time in a county, ranging from six to fourteen days, to cover the entire county. One day is spent around each community center and four to eight meetings are held in the barns surrounding the market or community center. A night round-up meeting is held in the town hall or church or elsewhere. Moving pictures are shown and general discussions conducted regarding the subject. There has been a great demand for this sort of work and it will, no doubt, be continued during the coming year.

Members of the department have also attended farmers' institutes and meetings, and we have furnished judges for the livestock at many county and district fairs.

One value feature of the extension work during the past year is shown by the increase in the number of cow testing associations from eleven to twenty, of which sixteen are in active operation.

ADVANCED REGISTRY.

The result of the official testing for the past year shows an increase in the semi-official work with a slight decrease in the official work. There were 1230 seven day records, 183 thirty day records and 42 thirty pound records compared with 1330 seven day records and 59 thirty pound records for the previous year.

The semi work is shown by herds, 96 herds being under supervision at the present time and approximately 520 cows, as compared with 87 herds for the closing of the previous year, showing an increase of a little over 10%.

Breed	Number of Herds
Holstein-Friesian	40
Jersey	20
Gurensey	34
Shorthorn	1
Ayrshire	1

There have been some very creditable records made this year, including several state records and one World's record for the Guernsey breed, both in the single and double letter class of Junior two year olds.

Respectfully submitted,
O. E. REED,
Professor of Dairy Husbandry.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF FARM CROPS.

President David Friday,
Michigan Agricultural College.

My dear President Friday:

Opportunity was given during the past year for the development of several new courses in Farm Crops, which were presented for the first time in addition to the basic courses previously established. Assistant Professor Cormany reports that seventy-four men were enrolled in the newly established potato, sugar beet and root crop course—Farm Crops 7, offered for juniors. Ample material was available for varietal studies, seed studies, and the study of market requirements. Forty-five men took the new course, Farm Crops 6—Crop Ecology. This field offers ample opportunity for the development of a strong course. The advanced work with cereals and forage crops has been given greater strength by placing all of the cereal seed work in the fall term course for seniors, known as Farm Crops 3, and providing for equal opportunity for forage crop seed study during the laboratory hours accompanying Farm Crops 4.

The laboratory equipment was increased by the addition of a moving picture machine and four new cases for class material collected during the year.

The following is a condensed statement of courses presented:

Farm Crops 1—Cereals:—Three credit freshman course. Two lectures and two laboratory hours per week. One hundred and eighty-three students.

Professor J. F. Cox and Instructor J. R. Duncan.

Farm Crops 2—Forage Crops:—Two credit sophomore course. Two two-hour lecture-laboratory periods per week. Seventy-nine students.

Assistant Professor C. R. Megee and Graduate Assistants.

Farm Crops 3—Advanced Cereals:—Five credit senior course. One lecture and three laboratory hours per week. Fifty-one students.

Assistant Professor A. L. Bibbins,* Assistant Professor C. E. Cormany and Instructor J. R. Duncan.

Farm Crops 4—Advanced Forage Crops:—Five credit senior course. Three lectures and two laboratories per week. Thirty-two students.

Assistant Professor C. R. Megee and Assistant Professor C. E. Cormany.

Farm Crops 5a—Plant Genetics:—Five credits, juniors and seniors. Three students.

Professor F. A. Spragg, Mr. E. E. Down and Graduate Assistant H. M. Brown.

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*Resigned Jan. 1, 1922. Mr. G W. Putnam appointed assistant professor in Farm Crops, Jan. 1, 1922.

Farm Crops 5b—Plant Breeding:—Five credit senior course. Three students.
  Professor F. A. Spragg and Mr. E. E. Down.
Farm Crops 6—Crop Ecology:—Five credit senior course. Three lectures and two laboratory periods. Fifty-three students.
  Professor J. F. Cox, Assistant Professor G. W. Putnam and Assistant Professor C. E. Cormany.
Farm Crops 7—Potato, Sugar Beets, and Root Crops:—Three credit junior course Two lectures and one laboratory per week. Seventy-six students.
  Assistant Professor C. E. Cormany.
Graduate students—eight.
Short Course—fall term, first year—sixteen weeks. Sixty-two students.
  Assistant Professor C. E. Cormany and Instructor J. R. Duncan.
Two-year six-weeks' course. Twelve men.
  Assistant Professor C. R. Megee and Instructor Duncan.
Short course—winter term. Twelve men.
  Assistant Professor C. E. Cormany.
Winter term eight-weeks' course. Forty-eight men.
  Assistant Professor C. R. Megee and Instructor J. R. Duncan.

SUMMER COURSES 1922.

Farm Crops 3—Eight students.
  Assistant Professor C. E. Cormany.
Farm Crops 4—Ten students.
  Assistant Professor C. R. Megee.
Special ten-weeks' course for High School Principals.
Professor J. F. Cox, Ass't. Professor C. R. Megee and Ass't. Professor C. E. Cormany
A two weeks' school for High School Teachers—Smith-Hughes plan. Thirty students.
  Professor J. F. Cox and members of the Crops Department.

I am certain that the recently authorized addition of two half-time graduate assistantships and two quarter-time graduate assistantships will greatly strengthen the laboratory and research work.

The number of inquiries received from farmers by mail relating to crops questions has greatly increased. Eleven thousand, four hundred and eighty first-class letters were written by experiment station and college workers in the Farm Crops Department, and eight thousand, four hundred and seventy-five first-class letters by extension men in Crops, or a total of nineteen thousand, nine hundred and sixty-one letters in answer to crops inquiries. In addition a large number of inquiries were answered by appropriate bulletins or circulars.

I take great pleasure in reporting the past year as one of progress characterized by the earnest endeavor and loyal support of all members of the Crops Department.

Respectfully yours,
J. F. COX,
Professor of Farm Crops.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF FARM MECHANICS.

President David Friday,
M. A. C.

Dear Sir:

I have the honor to transmit herewith the report of the Department of Farm Mechanics for the year 1921-1922.

INSTRUCTION.

The personnel of the department for the past year was as follows:

REGULAR COURSES.

H. H. Musselman, Professor.
E. C. Sauve, Assistant Professor.
F. E. Fogle, Assistant Professor.
G. A. Getman, Instructor (part time) tractors.
R. Hammond, Instructor, in charge of equipment and Assistant in Short Courses.
Daniel Shafer, Instructor in Blacksmithing.
Miss Gladys M. Sunday, Stenographer (part time).

SPECIAL COURSES.

R. E. Walker, Carpentry.
H. J. Gallagher, Farm Buildings and Conveniences.
B. O. Powell, Tractors and Gas Engines.
R. F. Leland, Truck & Tractor Courses (Trucks and Ignition).

The enrollment in the various courses offered is as follows:

REGULAR COURSES.

Farm Machinery—F. M. 4	12
Farm Drainage and Land Clearing—F. M. 7	5
Power Machinery—F. M. 3	24
Cement and Concrete—F. M. 8	17
Farm Conveniences—F. M. 6	21
Farm Structures—F. M. 5	8
Total	87

SHORT COURSES.

Gas Engines and Tractors	33
Gas Engines and Tractors	83
Truck and Tractor (Special)	93
Creamery Mechanics	30
Horticultural Mechanics	35
Farm Engineering (Special)	5
Farm Conveniences	22
Farm Structures	17
Forge Shop	82
Wood Shop	82
Total	482

The variety of work possible to offer has made a number of courses necessary, especially to satisfy the short course men. The problem of scheduling these courses with limited space and equipment has not been an easy one. Our Senior Optional Courses,—Power Machinery, Farm Structures, and Farm Drainage and Land Clearing have not had as high an enrollment as might be desired, but as this is the first year these courses have been given in the senior year, it is felt that the plan will be better understood next year. The plan of holding four tractor courses of one month each has brought about the same number of students—100, as the two courses of one month each previously given, with a greatly reduced teaching force and more effective individual work as well as less difficulty in organizing for the use of space and equipment.

All shop work will be given next year in co-operation with the Engineering Division. The razing of the Farm Mechanics Shop and the increase in the amount of horseshoeing and repair work by the Farm and Horse Department has made it seem desirable to transfer the blacksmith to that department, and this has been done. It is perhaps worthy of note that 3554 students, the greater majority of whom have been farm boys, have had instruction in this building in either Wood or Forge work or both. Work in this shop has always been kept closely related to farm practice. Many of the short course men taking these courses have considered them the most practical for their needs that the College has had to offer. The rugged manhood of Instructors Watt (deceased) and Shafer, is known and respected in every corner of the State by the men who have taken work in this building.

An attempt was made this year to introduce some land clearing into the course in Drainage. This cannot be handled in the most efficient way without seeing actual conditions and studying methods somewhat in detail from a practical standpoint.

The equipment of the department is housed in various places about the campus. Adequate space where the equipment could be grouped with central service and administration, would increase the efficiency with which work can be given. We also need some show space for exhibits, representative tools and machinery. Buildings, implements and machinery with which this department is concerned represents one-third of the investment in farms (1920 Census) of Michigan. It would seem that a factor in the farm business of the magnitude represented by this investment should have worthy representation in the work of the Institution, and a center for these interests in the way of housing which can be recognized as such.

It is perhaps not necessary for me to recite other needs of the department at this time. However, some expansion must come if we are prepared to do the work which we may be called upon to do.

The application of farm mechanics to practical conditions usually means the solution of a specific problem for an individual. A great deal of our time must necessarily be spent this way if we are to keep in touch with developments. Also, problems are varied and small in single applications but great in the aggregate.

The reports of this department on Extension and Experiment Station work will be found with the reports of these Divisions respectively.

I am indeed grateful for the support I have been accorded in the department and the assistance I have received from other departments. We are especially indebted to the Engineering Division for the use of space and for assistance rendered through Prof. Dirks in conducting our Tractor Courses.

Yours respectively,
H. H. MUSSELMAN,
Professor of Farm Mechanics.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF FORESTRY.

The President,
Michigan Agricultural College.

Sir:

I have the honor to submit the following report for the Department of Forestry for the year ending June 30, 1922:

The work of instruction was carried on during the year as described in the college catalog. The increased enrollment of students in forestry has necessitated dividing some of the classes into two sections owing to limited laboratory space, but it has been possible to arrange these sections so that the work could be efficiently handled. No changes were made in the personnel of the department during the year.

The teaching work was as follows:

	Number of Classes	Number of Students
A. K. Chittenden	9	267
P. L. Buttrick	8	159
G. A. Garratt	8	139

The forestry summer school was again held on the lands of the East Jordan Lumber Company near Green River, the Company furnishing us with the use of much equipment needed to operate the camp. A high quality of work was performed by the students. I wish to take this opportunity of expressing our appreciation of the kindness of the East Jordan Lumber Company in allowing us the use of their camp and lands for this purpose.

The forest nursery was operated as usual, planting stock to the amount of 110,000 trees having been shipped during the year. Thinnings were made in many of the forest plantations near the College, and studies were made of the rate of growth of the experimental forest plantation near Grayling. The maple sugar bush was operated with the usual yield of syrup.

Much work was done in identifying and cataloging the very complete collection of woods belonging to the College. Our collection of tropical woods is unique and offers an excellent field for graduate study.

The department has been represented at a considerable number of meetings throughout the State during the year, and has taken an active part in the formulation of a forest policy for the State. There is a constant need for an Extension Specialist in Forestry and I hope that it will soon again be possible to fill this position.

Respectfully submitted,
A. K. CHITTENDEN,
Professor of Forestry.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF HORTICULTURE.

To the President:

Dear Sir: I herewith submit the following report for the Department of Horticulture and Landscape Gardening for the year ending July 1, 1922.

The personnel of the department during the past year was as follows:

C. P. Halligan, Professor.
R. E. Marshall, Associate Professor.
R. E. Loree, Assistant Professor.
Thos. Gunson, Assistant Professor.
N. L. Partridge, Assistant Professor.

It is a pleasure to report that the classes in Horticulture have shown a more earnest and serious attitude toward their work than any of the classes since the close of the war. The courses in Horticulture, as outlined in the last catalogue, were offered for the first time during the past year. The changes made have permitted a greater degree of flexibility in the selection of courses to fit the particular requirements of the student. From the experience of the past year they appear quite satisfactory.

In the development of the work in Horticulture, several more changes should be made to meet the growing demands in this line of work. At present a student must elect for specialization, during the junior and senior years, either pomology or landscape gardening. New courses should be added to give the opportunity for specialization in vegetable gardening and floriculture. These industries are both of great economic importance in Michigan. As soon as facilities are available, it is also desirable to offer courses in horticultural products, to include work in canning, drying, the making of fruit juices and otherwise utilizing various horticultural crops.

The courses in landscape gardening at present are largely confined to students specializing in this subject. The only course otherwise offered is a three credit course in the spring term required of all horticultural students. It would seem desirable that all agricultural students should take at least one course in this subject to develop their appreciation for rural beauty and to learn some of the basic principles of laying out the farm home grounds. There is also an increasing demand for extension work along this line in directing and promoting the beautifying of rural towns and homes.

Respectfully submitted,
C. P. HALLIGAN,
Professor of Horticulture and Landscape Gardening.
East Lansing, Michigan, June 30, 1922.

REPORT OF FARM MANAGEMENT TEACHING.

President David Friday,
Michigan Agricultural College.
Dear Sir:

During the year 1921-22 the Farm Management Department gave courses to college, federal, and short course men, and also gave a special course of lectures at the summer conference of teachers in Smith-Hughes high schools.

Material for a course in Farm Organization and Farm Accounting has been gathered, organized, and mimeographed for classroom use.

Material for a high school course in Farm Accounting has been assembled and arranged in outline form and furnished to high school teachers of agriculture. This material was used as a regular basis of high school teaching in fifteen high schools and promises to be used in about double that number next year.

Much work was also done with high school teachers of agriculture in the matter of handling "home projects" in farm accounting. Under the plan of this project, the boy on the thirty-first day of December of his junior year in high school, takes an inventory on the home farm. He begins keeping financial, feed, and yield records which he continues for twelve months, at the end of which time, he takes a closing inventory. The year's records having thus been completed he is ready for his summarization, which he does in the farm management class during the remainder of the senior year. By introducing this work into the high schools of the State, large numbers of our future farmers are trained each year in careful business methods, and the use of farm accounts is taught in an extensive and efficient way.

The following is a list of the subjects taught by the Farm Management Department during 1921-1922 together with the number of students taking each subject.

COLLEGE.

	Term	Number of Students	
Farm Organization and Farm Accounts..	Fall	69	
Farm Business Methods	Spring	26	
Farm Organization and Farm Accounts..	Summer	12	
Total			107

FEDERAL MEN.

Farm Management and Farm Accounting	Spring	15
Co-operation and Marketing...........	Spring	25
Total		40

SHORT COURSE.

Co-operation and Marketing...........	Fall and Winter	39	
Rural Credits	Fall and Winter	29	
Farm Business Methods	Fall and Winter	4	
Farm Management	Fall and Winter	46	
Accounting Dairy Manufacturing......	Fall and Winter	33	
Agricultural Arithmetic	Fall and Winter	9	
Farm Accounting	Fall and Winter	88	
Total			248
Grand Total			395

Respectfully submitted,
HOWARD M. ELIOT,
Professor of Farm Management.

East Lansing, Michigan, June 30, 1922.

REPORT OF DEPARTMENT OF POULTRY HUSBANDRY.

President David Friday,
Michigan Agricultural College.
Dear Sir:

I have the honor to submit the following report of the Department of Poultry Husbandry for the year ending June 30, 1922.

Poultry farming is becoming one of Michigan's largest and most important agricultural industries. Numerous reasons can be given why this State is so excellently adapted to this form of specialization, but the "hen" is the greatest reason. During periods of depression, such as have been recently experienced, the farm and commercial poultry flock continued to return a satisfactory profit. Michigan holds a foremost position as a poultry state; the poultry and poultry products of this State have an estimated value of approximately forty millions of dollars.

The Poultry Department of Michigan Agricultural College is not functioning to full capacity in promoting this great industry. The demands for pedigreed cockerels and breeding stock cannot be met because the plant is inadequately equipped for the production of high class stock in quantity. The egg production standard for the State will continue to suffer so long as the combined instruction and extension force is limited to three men. The demand for assistance in conducting culling demonstrations, poultry certification and demonstration farms by County Agents and commercial poultry producers would require least at the services of three field men.

Poultry house plans, numbering approximately 5,000 have been distributed showing the construction of a modern building with special features of lighting and ventilation incorporated, yet visitors are disappointed to find the College Poultry Department has no building of this design available for inspection.

A number of changes have occurred in the personnel of the department this past year. Upon the resignation of Professor C. H. Burgess, Mr. Wilson Newlon was appointed Acting Head, working in this capacity until December 1st, 1921, when E. C. Foreman was promoted from Extension Specialist to Associate Professor and given charge of the department. Mr. Newlon received an appointment as Poultry Extension Specialist from California which was accepted and became effective January 1st, 1922. C. M. Ferguson joined the Extension Staff January 7th, 1922. He has had extensive experience in extension work in Ontario and is particularly well qualified for this position. An aggregate of 320 students have been enrolled in the classes for the year ending June 30th, 1922. This number includes regular, federal and short course students. Instruction to these students was given by Mr. George Davis, Assistant Lecturer, myself, and Dr. Chamberlain and Dr. Hallman of the Veterinary Division.

In addition to instruction given the students the department has a large correspondence and further demands are made to do standard and utility judging, attend poultry meetings, organize poultry associations, conduct county poultry short courses, demonstrate poultry culling, in addition to experimental and regular plant work.

Respectfully submitted,
E. C. FOREMAN,
Associate Professor of Poultry Husbandry.
East Lansing, Michigan, June 30, 1922.

REPORT OF THE SOILS DEPARTMENT.

President David Friday,
College.
Dear Sir:

It is with gratification that I present to you for the first time the report of the Soils Department. There are several phases of the educational work that I desire to bring to your attention. It does not seem possible that a student who spends as many hours each week in the class room and laboratory, as many of our students do, is able to devote sufficient time to original work. In other words he is not thrown upon his own resources to a sufficient extent. It is my firm conviction that it is wrong pedagogically, as well as uneconomical. We should be able to alleviate this condition, however, when the new library building is well stocked with proper volumes.

It is my judgment that the educational or extension work in soils in the State is of utmost importance. It is true that there is a tremendous shortage in acreage of leguminous crops and also in the production of barnyard fertilizers. The latter is largely dependent upon the former, whereas the legume situation is due in the main to soil conditions. Another point worthy of consideration is, the superior varieties of grains and other crops remain so for a relatively short time when widely disseminated on unfertile soils.

We are not in a position to meet satisfactorily many inquiries for information along the various lines; in fact, during the past year the department has received and examined 1500 samples of soil. It is interesting to note also that the majority of the samples were sandy in nature. It is not possible for us to do much more along extension lines without seriously interfering with the researches of the department, and where men are engaged to conduct certain projects, it is their duty to do so enthusiastically and to the fullest extent of their ability. I do not consider therefore that this phase of our work is receiving justifiable financial support. The following financial situation may be offered in support of this statement:

Name.	Salary.	Expenses.	Total.
G. M. Grantham	$1,200 00	$600 00	
P. M. Harmer	800 00	600 00	
Gertrude Meehan	675 00	....	
Supplies		200 00	
Total	....	....	$4,075 00

The College was fortunate indeed in having the American Association of Soil Survey Workers meet here November 18th and 19th. This meeting was attended by about fifty workers in soils, representing many states extending from California to Delaware, as well as the Canadian provinces.

The Soils Section has a member on the committee for the improvement of soil maps, correlative laboratory work of value to soil survey, and classification of organic soils respectively. The co-operative soil survey work is progressing satisfactorily. We now have an especially strong group of men at work in the field. At the close of this mapping season, Ontonagon, St. Joseph, Berrien, Kalamazoo and additional counties should be completed.

It is our policy—in fact the Soils Section was organized on this basis—to make it possible for each member of the staff to engage in some research or investigational work part of each year, as well as to encourage graduate students. We appreciate fully the necessity of such work for the maintenance of a live organization.

In closing I desire to extend to you the support of the members of the Soils Department both individually and collectively.

Respectfully,

M. M. McCOOL,
Professor of Soils.

East Lansing, Michigan, June 30, 1922.

REPORT OF DEPARTMENT OF SPECIAL COURSES.

President David Friday,
Michigan Agricultural College.
Dear Sir:

I herewith submit the report of the work of the Department of Short Courses for the year ending June 30, 1922.

The twelve different short courses in agriculture offered by this department have been attended by 449 students. A detailed record of the various courses is given in the following list:

First year eight weeks' course	34
Second year eight weeks' course	13
First year sixteen weeks' course	69
Second year sixteen weeks' course	24
Poultry	21
Truck and tractor course	63
Cow testing and dairy barn management	50
Horticultural course	35
Dairy manufactures' course	32
Dairy production	33
Farm engineering	7
Farm business	5
Ice cream manufactures' course	22
Special courses	18
Total	449

Mr. Ashley M. Berridge, Associate Director of Short Courses took entire charge of the work during the period between October 15th and March 15th. The successful management of these courses and of the short course men was due to the untiring efforts of Mr. Berridge.

Besides the regular instructional class work, weekly literary meetings, featured by speeches and motion pictures were held, athletics were encouraged and a choral club and an orchestra were organized with the short course men. Mr. E. C. Sauve directed the choral club. Miss Delia H. Bemis directed the short course orchestra. Mr. Larry Kurtz had charge of the basket ball team. The foregoing arrangements were planned in order to properly provide for the social and physical needs, as well as the strictly educational requirements of the students.

The annual livestock judging contest was another feature of the past year. Mr. Wesley T. McCalla, a first year sixteen weeks' man was the individual high point winner and received the cup offered annually by Dean R. S. Shaw.

The first annual Creamery and Field men and Operators Short Course of one week was scheduled for the first time this year. Its success insures it being an annual feature. The men attending this course were not counted in the grand total of short course students.

The two weeks' Cow Testing and Dairy Barn Management Course will not be offered the coming year. The two, four weeks' poultry courses will in the future be combined into an eight weeks' course. The Dairy Production and Dairy Manufacture courses are planned to cover a twelve weeks period instead of eight, for the coming year.

The plan of having four 4 week Truck and Tractor Courses instead of two, worked out very advantageously. It resulted in greater economy in instruction due to the better distribution of time.

Farmers' Week, a feature of our short courses, was under the direction of Mr. Berridge and was a marked success from all angles. The programs, exhibits, parades and shows, were well conducted. The estimated attendance during this week was from 5,000 to 5,500 farmers and farmers' wives. The administration, faculty and student body co-operated to make this event an institutional rather than a divisional affair.

The Class Day Program held on March 1st was the closing feature of the years' short course work. Rev. W. W. Diehl and Dean R. S. Shaw gave the main addresses. Results of the livestock judging contest were announced and prizes awarded at this meeting.

The annual trip to the International Livestock and Hay and Grain Exposition was taken by forty short course men. While in Chicago the men also visited the large packing companies, the Grain Exchange and other large and notable enterprises. This feature of the short course work was well worth while.

Most of the short course instructional work was handled by the regular instructors and professors of the various departments. The following men, however, were paid all or in part from short course funds:

E. B. Hill, Director.
Ashley M. Berridge, Associate Director.
H. J. Gallagher, Instructor in Farm Mechanics.
Romaine Walker, Instructor in Wood Shop.
B. A. Powell, Instructor in Creamery Mechanics.
R. F. Leland, Instructor in Trucks.
George A. Getman, Instructor in Gas Engines.

Respectfully submitted,
E. B. HILL,
Director.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEAN OF ENGINEERING.

Mr. David Friday, President,
Michigan Agricultural College.

Dear Sir:

I have the honor to present my fifteenth annual report as Dean of Engineering.

PERSONNEL OF DEPARTMENTS.

Civil Engineering:

H. K. Vedder, Professor.

C. L. Allen, Associate Professor.

C. M. Cade, W. W. Hitchcock, B. K. Philp, R. G. Saxton, Assistant Professors.

F. A. Gould, Instructor.

Drawing and Design.

R. K. Steward, Professor.

L. N. Field, C. Newman, A. G. Scheele, Associate Professors.

C. L. Brattin, Miss C. Holt, J. E. Robertson*, J. W. Steward, E. H. Stewart, Assistant Professors.

Miss E. Butler, O. W. Fairbanks, J. Rising, Instructors.

Electrical Engineering.

A. R. Sawyer, Professor.

M. M. Cory, L. S. Foltz, Associate Professors.

E. E. Kinney, Instructor.

Mechanical Engineering.

H. B. Dirks, Professor.

P. J. Baker, G. W. Hobbs, W. E. Reuling, G. C. Wright, Assistant Professors.

J. A. Eicher, A. P. Krentel, D. T. Millard, G. J. Posthumus, C. N. Rix, B. Sangster, W. L. Watt, Instructors.

C. Crawford, Assistant.

Enrollment.

OFFICIAL FIGURES FOR 1921-22.

	Ch. E.	C. E.	E. E.	M. E.	Totals.
Seniors	8	26	18	25	77
Juniors	19	25	34	32	110
Sophomores	21	45	36	38	140
Freshmen	25	59	70	60	214
Totals	73	155	158	155	541

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*Half-time.

SUMMARY OF OFFICIAL FIGURES FOR 15 YEARS.

	Fresh.	Soph.	Junior.	Senior.	Totals.
1907–08	183	92	63	47	385
1908–09	186	104	62	58	410
1909–10	177	120	74	48	419
1910–11	176	130	76	58	440
1911–12	132	127	84	58	401
1912–13	146	106	89	53	394
1913–14	199	123	74	63	459
1914–15	142	126	86	58	412
1915–16	131	88	83	71	373
1916–17	127	88	64	68	347
1917–18	124	78	40	37	299
1918–19	132	57	32	23	245
1919–20	223	116	76	51	466
1920–21	214	150	88	70	522
1921–22	214	140	110	77	541

From 1907 to 1918, 1851 men enrolled as freshmen in engineering and from 1910 to 1921, 687 enrolled as seniors, the ratio of the latter to the former number is 37 per cent and measures approximately the average persistence of the entrants. The variation is from 18 to 58 per cent; the former due to the war "slump" and the latter to the after-war "come-back."

COURSES OF STUDY.

At your suggestion there has been established a course in *Engineering Administration* designed to meet the requirements of students who, in addition to a natural aptitude and liking for engineering careers, feel that the business phases of the engineering industries have a stronger appeal than the technical phases, and who sense in themselves the business, executive or administrative ability which could be developed by a college course not so severely technical as the usual type of engineering course.

It is believed that the trend of industrial development warrants the instruction of a portion of engineering students in the principles of economics, accounting, banking, business law, transportation, statistics, industrial management, relations and history, corporation finance, contracts and specifications, and business cycles.

In the new course about 20 per cent of the credits required for graduation will be devoted to the subjects listed in the preceding paragraph.

The technical courses will be modified so as to provide for all engineering students the instruction in elements of economics, in the sophomore year, before they choose between the technical and engineering administration groups.

A special bulletin, supplementing the college catalog has been published for the information of prospective students in the new course.

UNDER DISCUSSION.

On May 19, 1922, I attended a conference of representatives of the engineering schools of Iowa State College, Michigan Agricultural College, Northwestern University, Ohio State University, Purdue University, Universities of Colorado, Illinois, Iowa, Michigan, Minnesota, Nebraska, North Dakota, Wisconsin and Washington, to discuss the question of the desirability of five and six-year engineering courses.

The unanimous opinion of those present was that it is desirable, "in order to meet the constantly enlarging responsibilities of the engineering profession," to make "an advance in engineering education" by providing "five years of collegiate training for those engineering students whose aim is to become qualified to take positions among the creative leaders in the profession," and to this end it was recommended that changes in present curricula be made substantially as follows:

1. Remodel the present four year engineering curricula by substituting a substantial proportion of humanistic and fundamental subjects in place of an equivalent amount of advanced technical work. It is desirable that, so far as possible the curricula in the different branches of engineering shall be sufficiently uniform to permit students to defer their final choice of a specialty at least to the end of the second year.
2. Add a fifth year of advanced work, mostly or wholly technical, and specialized to such an extent as desired.
3. The first four years of work shall lead to a bachelor's degree and the fifth year to an advanced degree in engineering.

I agree to the principles above set forth and am supported in this by my colleagues on the Engineering Committee, and we are all of the opinion that the new courses in Engineering Administration, the establishment of which anticipated the Chicago conference, go far in the direction pointed out by that conference.

FUTURE DEVELOPMENTS OF ENGINEERING AT M. A. C.

In order that the instructional work in engineering be properly stimulating to teaching staff and students and in order that the College, through its engineering departments shall render maximum service to the State and to the Nation, it is important and necessary that research work be undertaken and consummated by us in certain fields of applied science and engineering art relevant to the several lines of instruction offered and pertinent to the industrial needs of the times.

Such work can be initiated and promoted by:

1. Graduate assistant-ships.
2. Investigations by members of the staff, so gifted, who should be enencouraged by lightened teaching schedules and the opportunities now offered for degree-work.
3. The appointment from time to time of full time research men.
4. Specialized rather than all-round teaching duties.
5. Organic connections between the College and the State departments and with industrial and municipal organizations desiring techncial information but lacking facilities for obtaining it.
6. The establishment of an Engineering Experiment Station. This type of organized investigation work is especially appropriate for land grant institutions and has already been established in the following states with definite annual budgets (as of 1921-22):

Colorado	$10,900
Illinois	93,110
Indiana	25,000
Iowa	45,000
Kansas	6,750
Kentucky	3,000
Maryland	6,500
Massachusetts	75,000
Missouri	7,500
N. Carolina	1,000
Ohio	14,800
Pennsylvania	8,200
Tennessee	1,500
Texas	3,000
Vermont	1,500
Washington	5,000
W. Virginia	6,000
Wisconsin	5,000

None of these received Federal funds for engineering research.

In my first annual report, June 30, 1918, I cited the following:

"The effect of engineering research is so great in stimulating the activities of professors and students, and in maintaining correct ideals with reference to all things mechanical, that no state college of engineering is to be regarded as performing its full function, which fails to devote a portion of its energies to such investigations."—Dean W. F. M. Goss, University of Illinois.

My colleagues and I are very pleased to feel that the spirit of research is to be encouraged at M. A. C., and wish to participate to the fullest extent of our abilities and resources.

In conclusion I express appreciation to the staff and students in engineering and to the authorities for co-operating in our tasks.

Respectfully submitted,
G. W. BISSELL,
Dean of Engineering.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF CIVIL ENGINEERING.

President David Friday,
Michigan Agricultural College.
Dear Sir:

In spite of many hindrances to effective work, the results achieved during the past year in this department of the College were better than we had reason to expect. Presumably on account of reduced College finances our teaching staff was cut and the schedule of classes, field-work and laboratories was necessarily carried out with seven instructors as against eight for the year before. This situation compelled the suspension of certain rules of practice in apportioning the teachers to the requirements of the schedule which has been followed for some years past. I believe in repeated drill, especially in the field-work which accompanies our courses in all kinds of surveying, and this drill should be given under constant and minute supervision. Experience has shown that an instructor can supply the required kind of supervision in the field, only when he has assigned to him for a given exercise not more than fifteen students. With larger classes in this kind of training the instructor can not observe at their first occurrence erroneous methods of performance by the students, as he must do if bad habits are to be corrected and avoided. Even smaller classes are required for laboratory work in hydraulics.

The department teaching staff for the year included the names listed below in the order of seniority of appointment. Instructor J. F. Gibbs withdrew at the end of the last college year and no one was appointed in his place.

H. K. Vedder, C. E., Professor of Civil Engineering.
C. M. Cade, C. E., Assistant Professor of Civil Engineering.
R. G. Saxton, C. E., Assistant Professor of Civil Engineering.
W. W. Hitchcock, C. E., Assistant Professor of Civil Engineering.
B. K. Philp, C. E., Assistant Professor of Civil Engineering.
C. L. Allen, C. E., Associate Professor of Civil Engineering.
F. A. Gould, C. E., Instructor in Civil Engineering.

The tabulation which follows will answer all questions with reference to the teaching schedule, the number of classes and the attendance therein.

CLASS WORK—CIVIL ENGINEERING DEPARTMENT FOR COLLEGE YEAR 1921-1922.

FALL TERM.

Class.	Subject.	Number of Course.	Instructor.	Number hours per week.	Number students in Class.
Sophomores	Surveying (Class)	C. E. 1a	Mr. Gould	2	16
Sophomores	Surveying (Class)	C. E. 1a	Prof. Philp	2	19
Sophomores	Surveying (Class)	C. E. 1a	Mr. Gould	2	24
Sophomores	Surveying (Class)	C. E. 1a	Prof. Cade	2	22
Sophomores	Surveying (Class)	C. E. 1a	Mr. Gould	2	23
Sophomores	Surveying (Field)	C. E. 1a	Mr. Gould	2	17
Sophomores	Surveying (Field)	C. E. 1a	Prof. Hitchcock	2	20
Sophomores	Surveying (Field)	C. E. 1a	Mr. Gould	2	12
Sophomores	Surveying (Field)	C. E. 1a	Prof. Hitchcock	2	11
Sophomores	Surveying (Field)	C. E. 1a	Mr. Gould	2	23
Sophomores	Surveying (Field)	C. E. 1a	Mr. Gould	2	21
Sophomores	Surveying (Class)	C. E. 1b	Mr. Gould	2	21
Sophomores	Surveying (Class)	C. E. 1b	Prof. Hitchcock	4	29
Sophomores	Surveying (Field)	C. E. 1b	Prof. Hitchcock	4	21
Sophomores	Surveying (Field)	C. E. 1b	Prof. Hitchcock, Prof. Saxton	....	29
Juniors	Mechanics	C. E. 4a	Prof. Allen	5	19
Juniors	Mechanics	C. E 4a	Prof. Vedder	5	14
Juniors	Mechanics	C. E. 4a	Prof. Philp	5	15
Juniors	Mechanics	C. E. 4a	Prof. Allen	5	16
Juniors	Mechanics	C. E. 4a	Prof. Cade	5	18
Juniors	Mechanics	C. E. 4a	Prof. Philp	5	20
Juniors	Adv. Surveying (Class)	C. E. 6a	Prof. Cade	2	27
Juniors	Adv. Surveying (Field)	C. E. 6a	Prof. Cade	4	15
Juniors	Adv. Surveying (Field)	C. E. 6a	Prof. Hitchcock	4	12
Juniors	Drainage (Class)	C. E. 18	Prof. Vedder	2	26
Juniors	Drainage (Field)	C. E. 18	Prof. Vedder	4	26
Seniors	Surveying Methods (Class)	C. E. 2	Prof. Philp	3	24
Seniors	Surveying Methods (Field)	C. E. 2	Prof. Philp	4	24
Seniors	Graphic Statics (Class)	C. E. 4d	Prof. Allen	2	24
Seniors	Graphic Statics (Lab.)	C. E. 4d	Prof. Allen	4	24
Seniors	Hydraulics	C. E. 5	Prof. Saxton	5	24
Seniors	Hydraulics	C. E. 5	Prof. Saxton	5	16
Seniors	Hydraulics	C. E. 5	Prof. Cade	5	22
Seniors	Hydraulic Laboratory	C. E. 5a	Prof. Saxton	4	12
Seniors	Hydraulic Laboratory	C. E. 5a	Prof. Saxton	4	12
Seniors	Bridge Stresses	C. E. 8a	Prof. Vedder	3	13
Seniors	Bridge Stresses	C. E. 8a	Prof. Vedder	3	11
Total				126	722

CLASS WORK—CIVIL ENGINEERING DEPARTMENT FOR COLLEGE YEAR 1921-1922.

WINTER TERM.

Class.	Subject.	Number of Course.	Instructor.	Number hours per week.	Number students in Class.
Sophomores	Sand, Cement & Concrete (Class)	C. E. 16a	Prof. Hitchcock	2	36
Sophomores	Sand, Cement & Concrete (Class)	C. E. 16a	Prof. Allen	2	25
Sophomores	Sand, Cement & Concrete (Field)	C. E. 16a	Prof. Hitchcock, Mr. Gould	4	30
Sophomores	Sand, Cement & Concrete (Field)	C. E. 16a	Prof. Allen, Prof. Cade	4	31
Seniors and Juniors	Agricultural Engineering	C. E. 3a	Prof. Cade	3	22
Juniors	Mechanics	C. E. 4b	Prof. Philp	5	16
Juniors	Mechanics	C. E. 4b	Prof. Cade	5	12
Juniors	Mechanics	C. E. 4b	Prof. Hitchcock	5	11
Juniors	Mechanics	C. E. 4b	Prof. Philp	5	16
Juniors	Mechanics	C. E. 4b	Prof. Cade	5	15
Juniors	Mechanics	C. E. 4b	Prof. Philp	5	14
Juniors	Mechanics	C. E. 4b	Prof. Hitchcock	5	13
Juniors	Sewerage (Class)	C. E. 19	Mr. Gould	3	16
Juniors	Sewerage (Class)	C. E. 19	Mr. Gould	3	11
Juniors	Topographic Mapping (Lab.)	C. E. 7a	Prof. Vedder	6	14
Juniors	Topographic Mapping (Lab.)	C. E. 7a	Mr. Gould	6	14
Seniors	Bridge Analysis & Design (Lab.)	C. E. 8b	Prof. Vedder	8	25
Seniors	Masonry and Arches (Class)	C. E. 9a	Prof. Allen	2	12
Seniors	Masonry and Arches (Class)	C. E. 9a	Prof. Allen	2	13
Seniors	Masonry and Arches (Lab.)	C. E. 9a	Prof. Allen	4	12
Seniors	Masonry and Arches (Lab.)	C. E. 9a	Prof. Allen	4	13
Seniors	Pavements (Class)	C. E. 10	Prof. Saxton	2	11
Seniors	Pavements (Class)	C. E. 10	Prof. Saxton	2	13
Seniors	Water Supply	C. E. 15a	Prof. Saxton	5	17
Seniors	State Highway Construction	C. E. 20a	Prof. Saxton	3	8
Seniors	Highway Law	C. E. 20b	Prof. Saxton	2	10
Total				102	430

CLASS WORK—CIVIL ENGINEERING DEPARTMENT FOR COLLEGE YEARS 1921-1922.

SPRING TERM.

Class.	Subject.	Number of Course.	Instructor.	Number hours per week.	Number students in Class.
Sophomores	Surveying and Leveling (Class)	C. E. 1c	Prof. Hitchcock	3	16
Sophomores	Surveying and Leveling (Class)	C. E. 1c	Prof. Hitchcock	3	15
Sophomores	Surveying and Leveling (Class)	C. E. 1c	Prof. Allen	3	16
Sophomores	Surveying and Leveling (Class)	C. E. 1c	Mr. Gould	3	13
Sophomores	Surveying and Leveling (Class)	C. E. 1c	Mr. Gould	3	14
Sophomores	Surveying and Leveling (Class)	C. E. 1c	Mr. Gould	3	10
Sophomores	Surveying and Leveling (Field)	C. E. 1c	Mr. Gould	4	17
Sophomores	Surveying and Leveling (Field)	C. E. 1c	Prof. Hitchcock	4	13
Sophomores	Surveying and Leveling (Field)	C. E. 1c	Prof. Hitchcock	4	31
Sophomores	Surveying and Leveling (Field)	C. E. 1c	Mr. Gould	4	14
Sophomores	Surveying and Leveling (Field)	C. E. 1c	Mr. Gould	4	9
Sophomores	Adv. Surveying (Class)	C. E. 6	Mr. Gould	3	16
Sophomores	Adv. Surveying (Class)	C. E. 6	Prof. Cade	3	14
Sophomores	Adv. Surveying (Class)	C. E. 6	Prof. Philp	3	13
Sophomores	Adv. Surveying (Field)	C. E. 6	Prof. Philp, Prof. Cade	4	29
Sophomores	Adv. Surveying (Field)	C. E. 6	Prof. Saxton	4	19
Juniors	Strength of Materials	C. E. 4c	Prof. Philp	5	20
Juniors	Strength of Materials	C. E. 4c	Prof. Philp	5	8
Juniors	Strength of Materials	C. E. 4c	Prof. Hitchcock	5	13
Juniors	Strength of Materials	C. E. 4c	Prof. Hitchcock	5	14
Juniors	Strength of Materials	C. E. 4c	Prof. Philp	5	14
Juniors	Strength of Materials	C. E. 4c	Prof. Cade	5	14
Juniors	Strength of Materials	C. E. 4c	Prof. Allen	5	14
Juniors	Railroad Surveying (Class)	C. E. 7	Prof. Saxton	3	14
Juniors	Railroad Surveying (Class)	C. E. 7	Prof. Cade	3	16
Juniors	Railroad Surveying (Field)	C. E. 7	Prof. Saxton	4	14
Juniors	Railroad Surveying (Field)	C. E. 7	Prof. Saxton	4	16
Juniors	Astronomy (Class)	C. E. 14	Prof. Vedder	2	14
Juniors	Astronomy (Class)	C. E. 14	Prof. Vedder	2	12
Juniors	Astronomy (Field)	C. E. 14	Prof. Vedder, Prof. Philp	2	14
Juniors	Astronomy (Field)	C. E. 14	Prof. Vedder, Prof. Philp	2	12
Juniors	Reinforced Concrete (Class)	C. E. 16b	Prof. Allen	3	25
Juniors	Reinforced Concrete (Lab.)	C. E. 16b	Prof. Allen	4	12
Juniors	Reinforced Concrete (Lab.)	C. E. 16b	Prof. Allen	4	13
Juniors	Surveying Methods (Class)	C. E. 2a	Prof. Cade	3	21
Juniors	Surveying Methods (Field)	C. E. 2a	Prof. Cade	4	21
Seniors	Thesis	C. E. 11	Prof. Vedder	20	26
Seniors	Contracts and Specifications	C. E. 13	Prof. Vedder	3	37
Seniors	Contracts and Specifications	C. E. 13	Prof. Vedder	3	35
Seniors	Theory of Structures	C. E. 21	Prof. Allen	4	25
Seniors	Road Construction (Class)	C. E. 17	Prof. Saxton	2	16
Seniors	Road Construction (Field)	C. E. 17	Prof. Saxton	6	16
Total				165	615

The following text-books have been used in our classes during the year: Merriman & Jacoby's Roofs & Bridges, Vols. I & III; Malcolm's Graphic Statics; Poorman's Mechanics; Hughes & Safford's Hydraulics; Hool & Johnson's Concrete Engineers' Handbook; Blanchard's American Highway Engineers' Handbook; Harger & Bonney's Highway Engineer's Handbook; Turneaure & Russell's Public Water Supplies; Metcalf & Eddy's American Sewerage Practice, Vol I; Hosmer's Astronomy; Boyd's Strength of Materials; Searles & Ive's Field Engineering, with tables; Breed & Hosmer's Surveying, Vols. I & II; Elliott's Engineering for Land Drainage and Tucker's Contracts in Engineering.

The total expenditure by the department during the year for all purposes except salaries has been $4,534.44. During the same period the sum of $603.00 has been turned in for class and examination fees. Our annual inventory for 1922 shows an aggregate of $21,406.85 as against $19,138.95 in 1921.

Respectfully submitted,
H. K. VEDDER,
Professor of Civil Engineering.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF ELECTRICAL ENGINEERING.

President David Friday,
Michigan Agricultural College.

Dear President Friday:

The personnel of this department:

Professor, A. R. Sawyer,
Associate Professor, M. M. Cory,
Associate Professor, L. S. Foltz,
Instructor, E. E. Kinney,
Stenographer, Miss Jennie Belle Allan (part time),

has remained unchanged from last year—except that Mr. R. D. Wyckoff has not been with us. Very little was done with radio study until the spring term when two seniors did some work.

We have now set up a sending station in a room intended for library purposes and are doing some experimental sending—hoping to co-operate with the many departments of the State in using it. The lack of definite information as to what wave length to use, is causing a delay in its use. A great day for Michigan Agricultural College will dawn when the departments actually use broadcasting methods for imparting public information.

The Engineering Departments of this College can be of very considerable value to the so-called State Departments in technical work, more than they have been in the past—with an outlay of relatively little money.

This department has been asked to assist the Utilities Commission by maintaining a standards laboratory for certifying to the accuracy of measuring instruments used by the Public Utilities of the State, the Board has authorized their part of it and I hope we may consummate this act of co-operation.

Another matter in which this department can be of service other than its regular instruction work, is to maintain a Meterman's School for several days each year where information can be brought together and given out concerning the use of electric meters of all kinds. Many state institutions do maintain such courses and they are very much appreciated by those who patronize them.

The teaching schedule remains practically the same as last year and will not be repeated.

Yours very truly,
A. R. SAWYER,
Professor of Electrical Engineering.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF MECHANICAL ENGINEERING.

Mr. David Friday, President,
Michigan Agricultural College.
Dear Sir:

The following is a report of the work of the Mechanical Engineering Department for the year ending June 30th, 1922.

The personnel of the department at the end of the year was as follows:

H. B. Dirks, Professor of Mechanical Engineering.
W. E. Reuling, Assistant Professor.
G. C. Wright, Assistant Professor.
G. W. Hobbs, Assistant Professor.
P. J. Baker, Assistant Professor.
A. P. Krentel, Foreman of Wood Shop.
G. J. Posthumus, Instructor in Wood Shop.
D. T. Millard, Instructor in Wood Shop.
W. L. Watt, Instructor in Machine Shop.
C. N. Rix, Instructor in Machine Shop.
J. A. Eicher, Instructor in Foundry.
B. Sangster, Instructor in Forge Shop.
E. C. Crawford, Laboratory Engineer.
Ray Pearson, Storekeeper.
Miss Jennie Belle Allan, Stenographer (part time).

Several changes were made at the end of last year—Mr. G. W. Hobbs, a graduate of M. A. C. with the class of 1910, was appointed to fill the vacancy caused by the resignation of Mr. Hewlett. Mr. Hineline, machinist, was released in order to decrease the salary budget of the department. The release of the machinist necessitated a decrease in the amount of repair work done in the department shops. Such repairs as were absolutely necessary were made by the instructional staff and student help.

The Farm Mechanics Department was again given assistance in the Truck and Tractor short course. Instruction was given by Mr. Sangster in the forge shop, and the equipment of the department was used in the courses in Ignition and Lighting, Truck Engines, and Carburetion.

In the summer school, instruction was given in several machine shop courses, sixteen men having been registered in this work. Mr. Wright had charge of the courses.

During the year a switch-board was added to the turbo-generator in the Engineering Laboratory, and the board was so wired that connection could be made to the power and lighting circuit of the Engineering Building. On dark days this equipment was used to decrease the load on the main power station. Several pieces of equipment were loaned to the department for test purposes, viz:, a gasoline engine driven pumping outfit, by the Novo Engine Co., and a water brake dynamometer for testing automobile engines by the Reo Motor Car Co. Through the influence of one of our students, Mr. R. E. Dunlap, the Globe Mfg Co., of Battle Creek, presented the department with a small air compressor, such as is used in garages.

Considerable testing of spokes and wheels was done during the year for the Motor Wheel Corporation, and some miscellaneous tests were run for the City of Lansing, and various cement block concerns.

During the year frequent shop visits were made to the Novo Engine Co., the Ryan-Bohn Foundry, the Atlas Drop Forge Co., and the Reo Motor Car Co., and appreciation is expressed for the courtesies shown on these visits.

I also wish to express my appreciation of the courtesies shown by the Novo Engine Co., the New-Way Engine Co., and the Prudden Wheel Co., during the investigations conducted by seniors as part of their technical work.

With the exception of the switch-board, the needs expressed last year are still present and I earnestly hope that the coming year will relieve this condition.

The optional courses of the senior year were divided as follows: Steam Engineering—2 men, Industrial Engineering—18 men.

I wish to express my appreciation of the work of the various members of the department during the past year.

The teaching schedule for the year is shown in the tables that follow.

Respectfully submitted,
H. B. DIRKS,
Professor of Mechanical Engineering.

East Lansing, Michigan, June 30, 1922.

TABLE 1.—CLASS WORK OF DEPARTMENT OF MECHANICAL ENGINEERING.

FALL TERM, 1921.

Class.	Subject.	No. of Course.	Teacher.	Hrs. per week each student.	No. of students.	Student hrs. per week.
Freshmen	Elements of Engineering	1	Mr. Bissell	1	199	199
Freshmen	Wood Shop	2d	Mr. Krentel, Mr. Posthumus	4	85	340
Freshmen	Forge Shop	3d	Mr. Sangster	4	100	400
Juniors	Steam Engines	7a	Mr. Dirks, Mr. Hobbs	3	84	252
Seniors	Boilers and Stokers	7c	Mr. Dirks	3	10	30
Juniors	Engineering Laboratory	13a	Mr. Reuling, Mr. Hobbs Mr. Baker	4	103	412
Seniors	Engineering Laboratory	13d	Mr. Reuling Mr. Hobbs	8	21	168
Freshmen	Wood Snop	31	Mr. Krentel, Mr. Millard	5	133	665
Sophomores	Forge Shop	41	Mr. Sangster	4	52	208
Seniors	Heat Treatment	43	Mr. Baker	5	21	105
Sophomores	Foundry	51	Mr. Eicher	4	60	240
Freshmen	Machine Shop	61	Mr. Wright, Mr. Rix	5	70	350
Juniors	Machine Snop	62	Mr. Wright. Mr. Watt	5	33	165
Senors	Machine Shop	63	Mr. Watt	5	15	75
Juniors	Seminar	71a	Mr. Dirks	2	36	72
Seniors	Seminar	72a	Mr. Dirks	2	25	50
Total					1,047	3,731

TABLE 2.—CLASS WORK OF DEPARTMENT OF MECHANICAL ENGINEERING.

WINTER TERM, 1922.

Class.	Subject.	No. of Course.	Teacher.	Hrs. per week each student.	No. of students.	Student hrs. per week.
Seniors	Industrial Management	5a	Mr. Wright	7	19	133
Juniors	Gas Engines	7b	Mr. Dirks, Mr. Hobbs	2	79	158
Juniors	Metallurgy	11a	Mr. Hobbs	2	31	62
Seniors	Timber Physics	11b	Mr. Hobbs	5	12	60
Juniors	Engineering Laboratory	13b	Mr. Reuling	4	103	412
Seniors	Heating and Ventilation	18a	Mr. Dirks	3	23	69
Seniors	Power Station Design	18b	Mr. Dirks	7	10	70
Seniors	Costs, Accounting, etc	18c	Mr. Bissell	2	74	148
Freshmen	Wood Shop	31	Mr. Krentel, Mr. Posthumus	5	57	285
Freshmen	Wood Shop	32	Mr. Krentel, Mr. Millard	5	75	375
Sophomores	Forge Shop	42	Mr. Baker, Mr. Sangster	6	37	222
Sophomores	Foundry	52	Mr. Baker, Mr. Eicher	6	34	204
Freshmen	Machine Shop	61	Mr. Rix, Mr. Watt	5	57	285
Juniors	Machine Shop	62	Mr. Wright, Mr. Watt	5	1	5
Juniors	Machine Shop	63	Mr. Wright, Mr. Watt	5	30	150
Juniors	Seminar	71b	Mr. Hobbs	2	26	52
Seniors	Seminar	72b	Mr. Dirks	2	25	50
Total					693	2,740

TABLE 3.—CLASS WORK OF DEPARTMENT OF MECHANICAL ENGINEERING.

SPRING TERM, 1922.

Class.	Subject.	No. of Course.	Teacher.	Hrs. per week each student.	No. of students.	Student hrs. per week.
Freshmen	Wood Shop	2d	Mr. Krentel, Mr. Posthumus	4	67	268
Freshmen	Forge Shop	3d	Mr. Sangster	4	54	216
Seniors	Factory Design	5b	Mr. Wright	7	19	133
Juniors	Engineering Laboratory	13c	Mr. Reuling, Mr. Hobbs	4	97	388
Juniors	Thermodynamics	17a	Mr. Dirks, Mr. Hobbs	4	72	288
Seniors	Technical Problems	19a	Mr. Dirks Mr. Hobbs Mr. Wright Mr. Baker	16	20	320
Freshmen	Wood Shop	32	Mr. Krentel, Mr. Millard	5	97	485
Sophomores	Forge Shop	42	Mr. Baker, Mr. Sangster	6	30	180
Sophomores	Foundry	52	Mr. Baker, Mr. Eicher	6	21	126
Freshmen	Machine Shop	61	Mr. Watt, Mr. Rix	5	66	330
Juniors	Machine Shop	62a	Mr. Watt, Mr. Wright	4	24	96
Seniors	Machine Shop	63	Mr. Watt, Mr. Wright	4	1	4
Juniors	Seminar	71c	Mr. Wright	2	27	54
Seniors	Seminar	72c	Mr. Dirks	2	20	40
Total					615	2,928

REPORT OF THE DEPARTMENT OF DRAWING AND DESIGN.

President David Friday,
Michigan Agricultural College.
Dear Sir:

I herewith present to you my sixth annual report as head of the Department of Drawing and Design for the year ending June 30, 1922.

The personnel of the department for the college year is given below:

R. K. Steward, C. E., Professor.
Chace Newman, Associate Professor.
L. N. Field, B. M. E., Associate Professor.
A. G. Scheele, A. M., Associate Professor.
J. W. Steward, B. M. E., Assistant Professor.
Miss C. L. Holt, Assistant Professor.
E. H. Stewart, B. S. in M. E., Assistant Professor.
C. L. Brattin, B. M. E., Assistant Professor.
Justus Rising, M. E., Instructor.
O. W. Fairbanks, B. S., Instructor.
*Miss Edith Butler, Instructor.

The department has again had an opportunity to work with smaller sections and I am convinced that our efficiency is materially increased from this fact.

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*On leave fall and winter terms.

The freehand drawing work has been elected by more students this year and I believe that a real need is being met. With the elective courses offered, a girl may receive all the training necessary to prepare her for the teaching of art in our Public Schools.

We have received visitors from other schools this year and their comments have been very gratifying to us.

This year the labor in the blue printing room has been handled entirely by the teaching force and up to June 1st, a total of 800 hours has been consumed. I believe this work should be handled by an expert who would be employed on a full time basis.

In closing, I have one suggestion to make concerning our grading system. Comparative charts are worked up from time to time showing the percentage of A's, B's, C's, D's, X's and F's given by the different departments, and I believe a few convocations for the entire teaching staff to discuss the system would lead to more uniform results in the college as a whole.

Again, I wish to express my appreciation for the support which has been given me during the past year by the members of the department staff.

The following is a teaching schedule of the department.

Respectfully submitted,
R. K. STEWARD,
Professor of Drawing and Design.

East Lansing, Michigan, June 30, 1922.

TEACHING SCHEDULE DEPARTMENT OF DRAWING AND DESIGN.

FALL TERM, 1921.

Class.	Subject.	No.	Instructor.	Hours.	No. of students.
Freshmen	Mechanical Drawing	4ab-1	J. W. Steward	6	22
Freshmen	Mechanical Drawing	4ab-2	Mr. Brattin	6	18
Freshmen	Mechanical Drawing	4ab-3	Mr. Rising	6	22
Freshmen	Mechanical Drawing	4ab-4	J. W. Steward	6	19
Freshmen	Mechanical Drawing	4ab-5	Mr. Brattin	6	20
Freshmen	Mechanical Drawing	4ab-6	Mr. Rising	6	20
Freshmen	Mechanical Drawing	4ab-7	J. W. Steward	6	18
Freshmen	Mechanical Drawing	4ab-8	Mr. Fairbanks	6	18
Freshmen	Mechanical Drawing	4ab-9	Mr. Rising	6	18
Freshmen	Mechanical Drawing	4ab-10	Mr. Brattin	6	20
Freshmen	Mechanical Drawing	4ab-11	J. W. Steward	6	20
Freshmen	Mechanical Drawing	4ab-12	Mr. Fairbanks	6	18
Freshmen	Freehand Drawing	1b	A. G. Scheele	10	19
Freshmen	Freehand Drawing Science	21a-1	Mr. Scheele	4	21
Freshmen	Freehand Drawing Science	21a-2	Miss Holt	4	28
Freshmen	Freehand Drawing Science	21a-3	Mr. Scheele	4	21
Freshmen	Freehand Drawing Science	21a-4	Miss Holt	4	28
Sophomores	Descriptive Geometry	5a-1	Mr. Field	6	15
Sophomore	Descriptive Geometry	5a-2	Mr. Stewart	6	12
Sophomores	Descriptive Geometry	5a-3	Mr. Stewart	6	16
Sophomores	Descriptive Geometry	5a-4	Mr. Rising	6	13
Sophomores	Descriptive Geometry	5a-5	Mr. Field	6	16
Sophomores	Descriptive Geometry	5a-6	R. K. Steward	6	19
Sophomores	Descriptive Geometry	5a-7	Mr. Stewart	6	18
Sophomores	Descriptive Geometry	5a-8	Mr. Fairbanks	6	17
Sophomores	Freehand Drawing	21b	Mr. Scheele	10	1
Sophomores	Freehand Drawing	1m	Mr. Scheele	10	4
Juniors	House Architecture	9	R. K. Steward	6	19
Juniors	Shades and Shadows	7-2a	Mr. Newman	6	12
Juniors	Shades and Shadows	7-2b	Mr. Newman	6	13
Juniors	Kinematics	6c-4a	Mr. Field, Mr. Brattin	4	16
Juniors	Kinematics	6c-4b	Mr. Field	4	15
Juniors	Adv. Freehand Drawing	1p	Mr. Scheele	6	5
Seniors	History of Art	2b	Miss Holt	3	9
Seniors	Mechanical Drawing (Ags.)	3b	Mr. Newman	6	12
Seniors	Freehand Drawing	1s	Mr. Scheele	4	7
Seniors	Freehand and Mech. Drawing	1c	Mr. Newman	10	10
Total					599

TEACHING SCHEDULE DEPARTMENT OF DRAWING AND DESIGN.

WINTER TERM, 1922.

Class.	Subject.	No.	Instructor.	Hours.	No. of students.
Freshmen	Machine Design	16a-1	Mr. Fairbanks	8	11
Freshmen	Machine Design	16a-2	Mr. Brattin	8	11
Freshmen	Machine Design	16a-3	J. W. Steward	8	11
Freshmen	Machine Design	16a-4	Mr. Fairbanks	8	23
Freshmen	Machine Design	16a-5	J. W. Steward	8	20
Freshmen	Machine Design	16a-6	Mr. Rising	8	20
Freshmen	Machine Design	16a-7	J. W. Steward	8	16
Freshmen	Machine Design	16a-8	Mr. Rising	8	14
Freshmen	Machine Design	16a-9	Mr. Newman	8	14
Freshmen	Machine Design	16a-10	Mr. Newman	8	20
Freshmen	Machine Design	16a-11	Mr. Field	8	16
Freshmen	Machine Design	16a-12	Mr. Fairbanks	8	19
Freshmen	Freehand Drawing	1h	Mr. Scheele	10	19
Freshmen	Freehand Drawing	21a-1	Mr. Scheele	4	14
Freshmen	Freehand Drawing	21a-2	Mr. Scheele	4	2
Sophomores	Descriptive Geometry	5b-1	Mr. Stewart	5	12
Sophomores	Descriptive Geometry	5b-2	R. K. Steward, Mr. Rising	5	13
Sophomores	Descriptive Geometry	5b-3	E. H. Stewart	5	14
Sophomores	Descriptive Geometry	5b-4	R. K. Steward	5	14
Sophomores	Descriptive Geometry	5b-5	R. K. Steward, J. Rising	5	13
Sophomores	Descriptive Geometry	5b-6	E. H. Stewart	5	15
Sophomores	Descriptive Geometry	5b-7	R. K. Steward	5	14
Sophomores	Descriptive Geometry	5b-8	Mr. Stewart	5	20
Sophomores	Freehand Drawing	1n	Mr. Scheele	10	6
Sophomores	Freehand Drawing	21c	Mr. Scheele	10	1
Juniors	Machine Design	6d-3a	Mr. Field	3	17
Juniors	Machine Design	6d-3b	Mr. Brattin	3	17
Juniors	Machine Design	6d-4a	Mr. Field	3	14
Juniors	Machine Design	6d-4b	Mr. Field	3	14
Juniors	Adv. Drawing and Color	1q	Mr. Scheele	6	8
Juniors and Seniors	Freehand and Mechanical Drawing	2c	Miss Holt, Mr. Newman	10	10
Seniors	Machine Design	6f	Mr. Brattin	6	18
Seniors	Adv. Drawing and Color	1t	Mr. Scheele	4	6
Seniors	History of Art	2e	Miss Holt	3	26
Total					482

TEACHING SCHEDULE DEPARTMENT OF DRAWING AND DESIGN.

SPRING TERM, 1922.

Class.	Subject.	No.	Instructor.	Hours.	No. of students.
Freshmen	Machine Design	16b-1	J. W. Steward	8	18
Freshmen	Machine Design	16b-2	Mr. Rising	8	20
Freshmen	Machine Design	16b-3	Mr. Brattin	8	15
Freshmen	Machine Design	16b-4	Mr. Stewart	8	16
Freshmen	Machine Design	16b-5	Mr. Rising	8	16
Freshmen	Machine Design	16b-6	Mr. Newman	8	13
Freshmen	Machine Design	16b-7	Mr. Stewart	8	14
Freshmen	Machine Design	16b-8	Mr. Fairbanks	8	13
Freshmen	Machine Design	16b-9	Mr. Rising	8	17
Freshmen	Machine Design	16b-10	Mr. Brattin	8	12
Freshmen	Machine Design	16b-11	J. W. Steward	8	15
Freshmen	Machine Design	16b-12	Mr. Fairbanks	8	14
Freshmen	Freehand Drawing	21a-1	Mr. Scheele	4	23
Freshmen	Freehand Drawing	21a-2	Mr. Scheele	4	15
Freshmen	Freehand Drawing	1j	Mr. Scheele	10	18
Sophomores	Freehand Drawing	1w-1	Miss Holt	4	12
Sophomores	Freehand Drawing	1w-2	Miss Butler	4	12
Sophomores	Freehand Drawing	1w-3	Miss Holt	4	20
Sophomores	Freehand Drawing	1w-4	Miss Butler	4	16
Sophomores	Freehand Drawing	1w-5	Miss Butler	4	12
Sophomores	Freehand Drawing	1w-6	Miss Butler	4	19
Sophomores	Freehand Drawing	1w-7	Miss Butler	4	7
Sophomores	Freehand Drawing	1w-8	Miss Butler	4	19
Sophomores	Freehand Drawing	10-o	Mr. Scheele	10	3
Sophomores	Freehand Drawing	21d	Mr. Scheele	10	1
Sophomores	Mechanical Drawing	3a	R. K. Steward	4	4
Juniors	Kinematics	6e-4a	Mr. Field	4	19
Juniors	Kinematics	6e-4b	Mr. Field	4	10
Juniors	Adv. Drawing and Color	1r	Mr. Scheele	6	6
Seniors	Freehand and Mech. Drawing	3c	Mr. Newman, Miss Holt	10	8
Seniors	Adv. Drawing and Color	1u	Mr. Scheele	4	7
Seniors	History of American Art	2d	Miss Holt	3	20
Sophomore (Special Section)	Descriptive Geometry	5a	Mr. Steward	6	4
Total					438

REPORT OF THE DEAN OF HOME ECONOMICS.

President David Friday,
Michigan Agricultural College.

My dear President Friday:

I have the honor to present the following report of the Division of Home Economics for the fiscal year ending June 30, 1922:

PERSONNEL OF DIVISION.

Mary E. Sweeny, Dean.
Anna E. Bayha, Associate Professor.
Louise I. Clemens, Assistant Professor.
Emma P. Garrison, Assistant Professor.
Winifred S. Gettemy, Associate Professor.
Rebekah M. Gibbons, Associate Professor.
Helen R. Goodrich, Associate Professor.
Irma H. Gross, Instructor.
Osee Hughes, Assistant Professor.
May Person Kirby, Assistant Professor and Assistant to the Dean.
Avis L. Sprague, Assistant Professor.
Ethel Taft, Instructor.
Marion L. Tucker, Associate Professor.
Lola G. Yerkes, Associate Professor.
Jule F. Nelson, Instructor.
Sylvia Borgman, Instructor.
Dorothy Shank, Assistant Professor.

STUDENT ENROLLMENT.

The total enrollment for the year 1921-22 was 528, showing an increase of 24% over the preceding year, the matriculation in the freshman class having increased 31% and in the summer school 80% over the previous record. The enrollment by classes was:

Senior	75
Junior	83
Sophomore	94
Freshmen	177
Specials	3
Summer School	96
	528

The work of the students showed definite improvement in standard and in seriousness of purpose, as evidenced by the fact that only 4.9% of the total enrollment were requested to leave college on account of unsatisfactory scholarship. Fifty per cent of these withdrawals were among the freshmen and thirty-three per cent among sophomores.

INSTRUCTIONAL FORCE.

Misses Minerva Fouts and Florence Stoll resigned and were married during the summer. Miss Cecil Van Steenburg resigned to follow graduate study, and Miss Hilda Faust and Louise Clemens were granted leave of absence for part of the year for further study. The following appointments were made:

Emma Garrison, B. S. Columbia: Assistant Professor of Home Economics.

Rebekah Gibbons, M. Sc. Pennsylvania State College: Associate Professor of Home Economics.

Irma Gross, B. Sc., Chicago University: Instructor.

Lola Yerkes, B. Sc., Columbia University: Associate Professor.

Dorothy Shank, B. Sc., Columbia University: Assistant Professor.

Jule Nelson, B. Sc. Purdue University: Instructor.

Marion Tucker, B. Sc. Columbia University: Associate Professor.

Sylvia Borgman, B. Sc. Minnesota: Instructor.

Mrs. May Person Kirby: Asked to take the duties of Assistant to the Dean.

COURSE OF STUDY.

Beginning with the opening of the college year the revised course of study became operative and it has far exceeded all expectations in the results accomplished. The students have expressed great satisfaction because of the freedom it gave for electing subjects in which they were especially interested, and for specializing in the varied lines of home economics work.

The Home Economics faculty has found that the revised course gives opportunity to present individual courses in a much more comprehensive manner and to raise definitely the requirement for the students. The teaching staffs in other divisions have expressed themselves as delighted with the possibility it affords for a wider election in their subjects and have observed that the young women are showing a keener interest in their respective subjects than before; and now that further pursuit of a subject is left with the student a broader type of college work will be voluntarily taken.

DEVELOPMENT OF THE WORK OF THE DIVISION.

BROADENING OF COURSES ALREADY OFFERED.

Fundamental courses have been strengthened and thirty per cent of the time formerly given to laboratory work was devoted to lectures, reports and discussions.

All field work begun spring term last year has been broadened and strengthened:

The problems in nutrition (H. E. 12a, b, and c), carried on as part of advanced dietetics last year, was offered this year as an elective course for all students but Food Majors, and as a required subject for them, with the possibility of doing a year's work in this field if desired. Last year it was an experiment both on the part of the College and the public school. However, the successful completion of two terms work warranted its incorporation as a permanent feature of the city schools' educational program and proved to the Home Economics Division that it was a type of field work with genuine educational values. The Division secured the active cooperation of (1) the Lansing Board of Health, which met part of the expense, furnishing careful medical examination of all children, and supplied school nurses to assist in following up children in nutrition classes; (2) the Board of Education and the Superintendent of Schools who not only furnished the scales but met a portion of the expense incurred and arranged for a place in the schools' daily schedule for the nutritional instruction. These boards, with the Home Economics students under the direction of Mrs. May Person Kirby, undertook a fundamental experiment in health education.

The primary value to the students of the year's work in Problems of Nutrition was (1) to give them a social point of view, an appreciation of different economic levels which exist and how home economics should function in these levels; (2) an opportunity to observe first hand the direct effect of improper feeding and (3) to teach them to assume and carry the responsibility for a definite piece of educational work. The instruction of the school children was planned and given by the students in the schools, and was followed up by home visiting. This field practice offered the student an opportunity to take an active part in a real educational organization, to study the normal recation of children to new types of instruction, to apply the theories of psychology, to develop a method of health instruction which would demonstrate to the school children the relation between food and health and themselves, and to observe the effect upon the family health of the expenditure of the family income.

The result achieved with the school children was to give (1) an understanding of the relation of health habits (food, sleep, fresh air) on the growth and development of their bodies, (2) a keen interest in their health as expressed by their weight and appearance and (3) to insure a family interest in the proper food and health habits.

GENERAL STATISTICAL DATA.

Number of children handled in nutrition classes: 444.

Number handled in small groups	375
Number handled by schoolrooms	164
	539
Less duplication	95
	444

Percentage of gain in excess of normal:

Children handled in small groups	51.4%
Children handled by schoolrooms	43.6%

Comparison of calls per hundred children for city nurses in two public schools of Lansing having similar home conditions:

	Franklin	Walnut
1920-1921	28	86
1921-1922	18	72
Decrease in No. of calls over preceding year	35%	16%

Franklin Avenue School had milk lunches in 1920-1921, and milk lunches and intensive instruction in 1921-1922; Walnut School had neither lunches nor instruction in 1920-1921, and milk lunches but no instruction in 1921-1922. No other contributing factors were reported by the City Department of Health.

A complete report of this work is appended.

The Home Care of the Sick (*H. E.* 30): was broadened both in the content of the course and its application. The laboratory was conducted in the bedrooms of the Home Economics Practice House where actual home conditions existed and in as many cases as possible human beings were used as subjects in practicing the principles of home nursing. The Division was fortunate in securing the services of Mrs. Harry Person, formerly Superintendent of the Polyclinic Hospital of Chicago, to whose technical knowledge of general and bedside nursing the success of the course is due.

Clothing (*H. E.* 50*a*): Students entering the freshman class fall into two general groups—those who have had several years work in Home Economics in the high school and those who have had no training. Such a difference in the preparation of students makes a real problem in the type of instruction and standards which could be demanded in the class room. The class was divided upon a basis of preparation and those having had previous training were given the problem of constructing children's clothes. Children from the faculty families were brought in, all types of children's clothes were designed, patterns drafted and the clothes made. Study of the commercial patterns for children showed that great numbers of them placed the weight of the garment at the wrong place on the child's body, taxing certain muscles, and that buttons were placed on the garment where the child could not fasten them. These, with many other hygienic aspects of clothing, were made a foundation of the study of its construction in this course.

Institutional Management (H. E. 20 and 21): The growth and development during the present college year of the work in institutional management has been rapid and exceptionally satisfactory. Last year the beginnings were made in institutional management, the work consisting largely of class instruction in laboratory and lecture and limited participation in the management of the East Lansing High School lunch. The Home Economics Division has run the East Lansing High School lunch room from January through June by classes in advanced institutional management, classified in the catalog as H. E. 21. The students have done all the buying, prepared all the food, made out the menus, handled all monies, paid all bills, kept all accounts under careful supervision. The students have obtained from this course the knowledge of what it means to run a lunch room and have obtained some experience in that kind of work which a large proportion of them meet in their teaching positions.

We believe this opportunity for actual experience in running lunch rooms is most important and should be continued. The project has netted $124.00 profit to the High School authorities and we have the approval of the authorities upon the way in which the course has been handled and the results obtained.

Woman's Commons: The college club known as C was, upon recommendation of the president, Dean Eudora Savage and the Board of Agriculture, placed under the direct supervision of the Home Economics Division in September 1921. Previous to this time no organic relation had been maintained between the Club C and the House Economics Division. The Division asked the change of name to Woman's Commons as similar organizations are designated in other institutions.

The expense of running the Commons as a dining room for women students has been borne by the College; that is, no rent, light, gas, or general overhead had been remitted to the College by the management, but had been paid by college funds. The Home Economics Division assumed complete responsibility for all expenses, including all overhead and service. There were no monies given the Commons with which to start the school year. At the end of the year, the Woman's Commons had paid to M. A. C. $1200 for rent and had met all expenses incurred. (See financial report). The Commons has also paid the salaries of Miss Nelson and Miss Borgman, and part of the salary of Miss Sprague.

In taking over Club C the Home Economics Division determined that its primary function was to provide clean, wholesome, properly chosen food for the women students, at a reasonable rate; that its secondary functions were to (1) put into practice home economics standards of food habits and theory; to include instruction in proper social behavior at meals; to introduce a type of service worthy of the dignity of a college dining room: and (2) provide a laboratory for instruction in Institutional Management.

A regular staff of help consisting of four cooks and twenty-five student waiters has been maintained during the year. The menus have been planned around the work which the Institutional classes have been able to do; that is, the method has been to use in the Commons the food products which the Institutional classes (H. E. 20) prepared. At no time, however, has the welfare or standards of food service been allowed to suffer because of the uncertainty of student production of food.

The Woman's Commons, being a new project, has met all the difficulties which any new piece of work is sure to encounter, not the least of which was the age of the equipment. There was only one electrical device in the kitchen, that being the dish-washer. In the fall term, when three hundred students per meal were fed, the shortage of equipment was a great hindrance, and the lack of understanding of the real purpose and function of the Commons was not clear to students; there was the usual human dissatisfaction when the food to which one is accustomed is changed, and there is offered a properly balanced ration.

At the beginning of the college year, salads and vegetables were disliked by most of the students and a large percentage served was uneaten at the end of the meals. In the spring term, a tremendous change was noticeable and students invariably consumed all vegetables and salads which were served. Numerous girls have spoken of the fact that they had learned to eat and like vegetables and salads which, when they came to the Commons, they would not touch. Undoubtedly, one of the outstanding achievements of the Commons has been that it has actually made the students see that their food theories and food habits function in their lives.

The menus served in the Commons have been studied by the classes in dietetics and criticized by students and professor for dietetic correctness, insuring this means of further educating the student to their value.

In the food classes, the girls recorded a two weeks' dietary of their own consumption. About half of these girls ate in the Commons and half outside. In every case, the girls eating at the Commons showed better chosen, higher caloried, and more satisfactory dietaries than the girls who ate outside.

The Commons management has maintained during the entire year the friendliest relationship with all its employees. Our endeavor has been to pay good wages to our help, believing that help so paid will co-operate in improving conditions. The fact that all of the student help have asked to return and that the regular staff has been practically the same through the whole year, demonstrates the value of such principles.

The results obtained financially prove the value of a trained management. $1905.00 has been spent in new equipment (for items see detailed report appended); $3300.00 is on deposit to the savings account of the Woman's Commons (account with J. Schepers, Treasurer, M. A. C.) and an inventory of supplies on hand at the close of the college year (June 23rd) of $1835.13. This, in view of the fact that the average rate of board was $4.70 per week, the lowest rate quoted by any state institution of equal rank to M. A. C., illustrates what proper institutional management can accomplish with sufficient authority to insure the proper distribution of the funds.

The fact that the Commons has, as all good sound business organizations must have, a considerable fund at the end of the year is to its credit and an index of its real success. If the Commons continues from year to year, the desirability and necessity of having this reserve fund would be apparent to all familiar with sound business principles.

Home Economics Education: The methods of teaching Home Economics given as a part of the preparation for the teacher training has been broadened and strengthened in content. The practice teaching has been conducted in the East Lansing High School and Haslett Consolidated School. Opportunity for teaching Foods and Clothing in the 7th and 8th grades was made possible and these classes met five times a week instead of three, as formerly. Each student taught a minimum of thirty lessons, half in foods and half in clothing.

NEW WORK UNDERTAKEN.

A number of courses which became a part of the curriculum when the revised course of study was approved by the general faculty and authorized by the State Board, have offered opportunity for valuable training to the student in field work and to the College for co-operation with a number of institutions and organizations with which it is fundamentally allied.

Field Work in Social Service (H. E. 13a, b, c): Through a co-operative project with the Social Service Bureau of Lansing, it has been possible this year for a limited number of senior Home Economics students to have the advantage of field work under the supervision of the director and staff of that organization.

The course has consisted of one lecture per week, given by the director of the Social Service Bureau, and of four hours of field work per week, with individual conferences regarding field work.

The object of the course was not primarily to train M. A. C. students to become social workers, although a few of those who enrolled in the course have such positions. The primary object was to socialize the point of view of the Home Economics trained woman, broadening her contacts and helping her to see the possibilities and responsibilities which lie before a woman with her training.

Nutrition Problems in Hospitals (H. E. 14a, b, c): This course was begun in the spring of 1921, when co-operation was established with the superintendent of Sparrow Hospital and students were permitted to work in the diet kitchen of the hospital under the direction of the hospital staff. During the present college year twenty per cent of the senior class have availed themselves of this opportunity to become acquainted with the nutrition problems in the hospital and to secure preliminary training as hospital dietitians. They have acquired knowledge and appreciation of the institutional problem involved in furnishing diets to patients, of the medical and nursing problem involved in nourishing the sick, and of the function of the dietitian in the general organization of such institutions. They have had actual practice in preparation of trays for patients and opportunity to observe the patient's reaction to food, problem of serving both from diet kitchen and from floor kitchens and wards of the hospital, preparation of special diets for nursing mothers, very young babies, operative cases and dietetic disorders, such as diabetes and nephritis. In addition they have assisted in the planning for meals of the medical staff, nurses and employees, the buying of all food supplies and the operating of the laundry.

In further co-operation with the board of directors of Sparrow Hospital, the senior class of nurses has come to the College one day per week for laboratory instruction in Dietetics. This instruction was given by a student enrolled in H. E. 13, under the supervision of the professor in nutrition; lectures in the same subject were given to the nurses at the hospital. This co-operative arrangement was most beneficial, both to the hospital and to the Home Economics Division.

The thorough character of the work and its successful application is due in no small measure to the tireless effort of Mrs. Harry Person and Miss Rebekah Gibbons, and to the smypathy and understanding of the hospital board and staff.

Special Investigations in Nutrition (H. E. 15): The students did either experimental animal work or, in co-operation with the Social Service Bureau, worked with city families in which there were distinct nutrition problems. Sometimes the work consisted in planning and supervising a revision of the food expenditure in cases where the income was sufficient if expert knowledge was available, but insufficient without it. In cases where the help of the city or some other agency was necessary, the amount of food required was decided and recommendations made for this aid to the proper authority. Two of the girls made a study of the children at the Social Center and then prepared weekly menus for them, also serving the supper to the children each week on the cook's day off.

The Home Economics Practice House: In September 1921 the Alumnae Council placed in the hands of the Dean of the Division $1,019, to be spent under her direction in furnishing a house, No. 9 Faculty Row, given to the Division for use as a Practice House. A co-operative committee from the Alumnae Council, a group of eight senior students resident in the Practice House, and a committee from the Home Economics faculty, formed a joint committee to recommend the purchases which should be made. The students were assigned the problem of surveying the most urgent needs for furnishings, of investigating prices and of recommending purchases to the other committees. This was valuable training for them in the handling of money, development of business standards, choice of furnishings, application of principles of house furnishing, textiles and applied design.

A few articles of furniture had at different times been purchased by the Alumnae, looking forward to the establishment of a practice house, and were temporarily placed in the Senior House. By order of Dean Shaw, acting president, these were transferred to the Practice House, together with such dining room and kitchen equipment as were owned by Club H (which was no longer functioning).

Within the Practice House a home life was maintained with a family of eight senior students and a resident instructor of the Home Economics faculty. All food was selected, purchased and prepared by students under direction. Weekly, an amount agreed upon was paid into house funds by the students; this money was spent and all accounts kept by them. The problem was one of applying principles of scientific management to routine of the home, of applying business methods to family expenditures, of applying the theory of nutrition, food preparation, textiles, to the actual everyday living under conditions simulating those of a normal home. Much was achieved in the six weeks' residence of the students in re-interpreting to them the social, ethical, and moral responsibility of the home. Within the year not all that should ultimately be accomplished by such a course was attained, but a significant beginning was made, which, with development, should prove of enduring value to the College, the Division, and the students.

Home Care of the Child (*H. E.* 34): This course was offered for the fall and spring terms at the College. It was primarily planned to be carried out in co-operation with the Merrill-Palmer School, but the demand was so pressing upon the part of the students that it was given on the campus also.

The co-operation of local physicians, nurses, specialists in child psychology, and child feeding was secured and participation in the courses shared. Laboratory instruction was given in child feeding, child care and hygiene, treatment of children's diseases, and students were assigned either groups of children to make a special study of and report, or were assigned to families to spend four hours weekly in the care and study of the children of the household. During the spring term an intensive study was made of the children in the Social Center, who come from disabled homes, and the effect of environment upon the normal development of the child.

Development of Home Economics (*H. E.* 49): Beginning with this year's freshman class, all students were required to take a course of lectures given by the dean of the division, dealing with the Development of Home Economics. The purpose of this course was to acquaint freshmen with the character of Home Economics as a profession, the opportunities for service afforded and the types of specialization offered. Heads of departments in the sciences (pure and social), English and language, art, and education were asked to address the class upon the relation of their subject to Home Economics. The State Leader of Home Demonstration, representatives from Public Health Nursing, Board of Health, Social Service Bureau, Tuberculosis Association, were invited to discuss with the students the relation of their profession or organization to Home Economics. The results obtained were a broader vision of Home Economics itself, of its relation to other professions, an understanding of the reason for requiring pure and social sciences, and the fundamental need in every day living for scientific knowledge of nutrition, hygiene, and sanitation.

A New Undertaking in Institutional Management: In February, 1922, the Home Economics Division assumed control of the Flower Pot Tea Room. This was particularly desired as a laboratory for students to give institutional training in tea room work. A trained instructor was employed as manager of the tea room and students were put in to do all parts of necessary work. Here the students obtain the view point of institutional management as a whole. They are able to do this more easily because of the smaller size of the tea room compared with the size of an organization such as the Woman's Commons.

In the Flower Pot, the students have had the additional problem of management to make a profit, which has not been any part of the training offered in the Woman's Commons. The tea room offers the additional opportunity of meeting the public face to face and finding out what the public wants, how it wants it, and the difficulties which must be met.

There was turned over to the Alumnae Council $465.00 in cash and $175.00 paid for debts incurred previous to our assuming control of the Flower Pot, which indicates the possibility of making a legitimate profit through organizations of this kind.

The field work in clothing has been no less significant and far-reaching than that in food and nutrition.

Clothing Problems (*H. E.* 54): This course involved a careful study of children's clothing in relation to health, personal comfort, cost, care, color, design, choice of material, convenience in manipulation, and a child's reaction to these. An investigation was made of the needs and problems in children's clothing and of the garments on the market. Some garments have been made which we feel are an approach to an ideal wardrobe for a child. This study revealed that the ready-made garments were not adequate in many respects, nor were the commercial patterns used by mothers for home-made garments entirely satisfactory.

Some of the problems worked out included—

Changes in the conventional methods of fastening boys' trousers:

a. Reversal of the placket.
b. Longer plackets.
c. Substitution of drop front for the fly.
d. Change of position of buttons.
e. Reduction of number of buttons.

Girls' dresses:

- a. Making of designs to simplify:
  - (1) The making and
  - (2) The laundering problem
- b. To make more comfortable for wearer
  - (1) Step-in dresses
  - (2) Step-in underwear
  - (3) Dresses with one or two practical front fastenings.

Pants, waists and harnesses that are cheap, easy to make and launder, distribute weight correctly, and cause no restriction.

Outer garments to replace coat:

- a. One with detachable inner lining.
- b. One with leggings and scarf attached—(These garments supply the needs of the coldest weather for outdoor play and eliminate the separate leggings, sweater, scarf, etc., which consume much time in dressing: the detachable inner lining makes it possible to wear the garment in milder weather).

Equipment (demonstration frames) for teaching the manipulation of fastenings such as snaps, hooks and eyes, buckles, etc., were made. Speed tests were given on these and reports made.

The laboratory procedure included the compilation of questionnaires which had been sent out to mothers of Michigan for data concerning children's clothing; personal interviews with Lansing and East Lansing mothers to learn their problems; investigation of children's garments in local stores, Detroit and other cities; bibliography of available material on children's clothing. Also, the making of dresses and suits according to commercial patterns, materials used in these garments having been carefully tested and recommended by Textile classes of 1920-21, subjecting these garments to test in the Merrill-Palmer school; the making of duplicates of this first set of garments with the corrections recommended by students in residence at the Merrill-Palmer School. These corrections were based upon the wearing test given the dresses and observations made on the clothes children brought from home.

The development of the following special projects was of economic and social significance:

Five and ten cent stores—investigation of store system, wages, articles of women's wear, etc., and comparison with other stores.

Trade names—for ready to wear dresses and blouses.

Investigation of trade-marked articles, demand for them, value of trade name to manufacturer, retailer, and consumer.

House dress for farm house—investigation of those on market and designing and making of a suitable type.

Clothing shop for children—investigation of children's clothing shops in Lansing, mail order business, and of most desirable lines to carry in such a shop.

Purchasing habits in stockings—A study of purchasing habits gained from college students and also from information from hosiery departments in Lansing stores: Special emphasis on popularity of certain trade-marked brands: Data on wearing qualities obtained from student records.

Baby layette—

Investigation of cost and number of articles in ready-made, comparison with home-made, planning of very inexpensive layettes and designing and making of one pattern adapted to several garments.

The students in residence at the Merrill-Palmer School have made a special study of the problem of designing and making simpler clothing for children, and simpler methods of fastening, a child's ideal outer garment to combine coat, leggings, scarf, and hood, garments on the market and the designing of patterns and the selecting of material.

This course gives evidence of the wide range of research problems open to women interested in textiles and clothing and the study of children's clothing, which has been only barely begun as a piece of experimental work and which, if continued, should be a worthwhile contribution not only the clothing work, but to the health of the child.

Field Work in Textiles and Clothing (*H. E. 55*): The purpose of this course was to enable the student to investigate lines of work other than teaching, to apply economic theory to clothing consumption, to study retail trade and business methods in use in the commercial world. Four students have chosen to work toward the position of buyer in retail stores and have spent the laboratory hours in salesmanship work in three of the Lansing stores.

Two other students wished to have more advanced work in clothing construction, especially in tailoring. They have worked with two of the Lansing tailors and with a leading modiste.

Another student has been interested in textile research. She has worked on the subject of shrinkage—the best method and the relation between price and quality and the amount of shrinkage. Home dyeing, stain removal and analysis of laundry soaps have also been worked on.

Field Work in Millinery (*H. E. 53b*): Out of a class of twelve students in Commercial Millinery, eight did field work in two different shops in Lansing. The class met regularly for three laboratory periods per week or six hours. During each student's shop experience, she was asked to report at only one class period; the other two days she worked in town, conforming to the rule of the shop as to hours—1 to 5:30.

With the co-operation of the person in charge of the work room, problems not carried out in class were given in the shop. In most cases, the students worked in shop for six half days, covering a period of three weeks.

It gave an insight into shop methods not possible to present in the school laboratory, and thereby helped her to be better prepared to teach in a vocational school.

The creative instinct is much more easily developed when one is surrounded by the materials with which to create.

It develops speed which is necessary in the successful creation of hats.

It gives the girls a sympathy and understanding of the workers in other fields.

From the standpoint of the consumer, it gives her a better idea of the real worth of a hat.

It helps the student to create hats for different types and ages, while in the school laboratory she works for herself or girls of similar age.

Co-operation with the Merrill-Palmer School—Detroit: In April, 1921, the Board of Agriculture and the Board of Trustees of the Merrill-Palmer School entered into a plan of co-operation by which six senior Home Economics students per term were permitted to study in residence at Detroit and to pursue intensive and special courses dealing with the care of children between the ages of fifteen months and five years (2) with the special nutritional problem involved in their feeding and (3) also with the social agencies dealing with the home.

The Merrill-Palmer School equipped a practice house for use as the residence of the M. A. C. students and placed at the disposal of the College, for the instruction of the students, their staff of specialists, consisting of Doctor Helen T. Woolley, Miss Lila Skinner, Miss Ellen Miller, Miss Henton of London, England. The Home Economics Division maintained one of its teaching staff, Miss Lola Yerkes, in residence at the Merrill-Palmer School. This instructor taught the home management practice and lecture (H. E. 31 and 32), and assisted in the care of children (H. E. 34) and special problems in nutrition (H. E. 15).

In January, under the direction of Doctor Woolley, the Merrill-Palmer School opened a Nursery School for children of pre-school age. The thirty-three children enrolled were under the direct instruction of Miss Henton of the Gypsy Hill Training School, London, England, an expert in methods of instructing children of pre-school age, who was granted a leave by the English educational authorities in order to assist in the establishment of a nursery school in the United States.

The students assisted the nurse every morning in the health inspection made of the nursery school children upon their arrival, weighed and measured them weekly, assisted the physician in making charts showing the results of their physical examination.

Three hours daily were devoted to laboratory observations of groups of the children and specific observations on definite children for the purpose of learning to determine and set standards for normal behavior, motor ability, memory, perception, and formation of habits at different ages. The students in groups planned and prepared the daily food eaten at the noon-day lunch by the children, sat at the table with the children and gained experience in the knowledge of how to give them the proper food habits.

A series of lectures, extending throughout the term, was given by an outstanding physician, dealing with the physical development and care of children; another series of lectures by an expert in field and laboratory work in sociology was given. Other persons of wide experience in special fields were invited to address the students.

The object of these courses was to round out the Home Economics training of the students. Home Economics should include, as a fundamentally important part of every college course, adequate instruction in the physical, mental and moral care and development of children. To develop such courses, both in content and method, was one of the purposes of establishing the Nursery School, and to give the student actual acquaintance with the behavior, mental habits, the proper method of instructing children, as well as standards for observing reactions and interpreting results.

The twelve students who studied in residence there have received (1) a knowledge and understanding of the standards to be maintained in the physical care of children. (2) Normal mental development and habit formation. (3) Proper food for children of pre-school age and its relation to growth and body efficiency. (4) The social and economic function of the home and its responsibility to the community. It is the hope of both the Merrill-Palmer School and the Home Economics Division that the experimental work done, the method evolved, and the subject matter formulated, will become the foundation for many such courses in other institutions and that later similar work may be given to every member of the senior class on the campus.

The home management practice was conducted much as it was done on the College campus. The spirit of a real home prevailed and all the activities were organized and carried on in a most efficient manner.

EDUCATIONAL WORK OFF THE CAMPUS.

In June, 1921, with the consent of President Kedzie, I planned to co-operate with Dean S. A. Courtis, Director of the Detroit Teachers College, in giving two courses of lectures in connection with the Evening School classes, one in the "Mal-nutrition of Children" and the other in "Saving and Spending". The course extended from October fifteenth to March twentieth and required my presence in Detroit one day per week. The matriculation in both courses far exceeded the most sanguine predictions and included largely principals, assistant principals, and special teachers and supervisors in the high schools of the city. In the course dealing with mal-nutrition, employees of the city board of health, (the physical education department), special schools and a majority of the home economics teachers, were enrolled. Much was accomplished in bringing to this important group the character of work being done at the College and the service it could render such city school systems. The fact that the total enrollment of students in the Division included less than twenty from Detroit confirms the need for making such educational contacts.

Several times during the year I conferred and advised the city school administrators in Grand Rapids regarding developing the work in Home Economics in the grades and high schools, also with the Y. W. C. A. in their plans for their educational foundation, to be established for working girls.

From July 1, 1921, to July 1, 1922, there were received one hundred and forty invitations to speak from women's clubs, schools, county extension agents, granges, leagues of women voters; of these it was possible to accept only 33; eight of these were requests from outside the State, at which it was to the advantage of the College to have a representative present. The home-maker in Michigan is keenly interested in the home economics education which the College is giving and wants to profit in her daily living by advice and information which can be given by our staff in public lectures. A very real educational service to the adult women of the State can be rendered in this way.

Mutually helpful co-operation has been maintained with the Home Demonstration work of the Extension Division of the College and the Supervisor of Vocational Education.

In closing the work which I have been able to do at the Institution, I wish to make grateful acknowledgment of the unfailing co-operation and service of the Home Economics faculty; it is to them that the accomplishments of the last year are due. I also wish to acknowledge the help and interest of other departments in further developing the work.

It is with profound regret that I terminate my connection with the Home Economics Division of Michigan Agricultural College, but I shall look forward to the development of its great possibilities and opportunities for service to the State.

Respectfully submitted,
MARY E. SWEENY,
Dean of Home Economics Division.

East Lansing, Michigan, June 30, 1922.

ANNUAL REPORT OF THE DEPARTMENT OF TEACHER TRAINING.

The Department of Agricultural Education was established July 1, 1908, as a department of the Division of Agriculture.

When the Smith-Hughes Law was passed in 1917, it became the Vocational Teacher Training Department of the College. In order to comply with said federal law and provide suitable training for teachers in vocational home economics and in vocational agriculture a teacher training and practice teaching school was installed.

During the current year about one hundred fifty (150) students have entered the classes in Education. The professional educational subjects are made electives in the junior and senior years, so that the class membership consists of both juniors and seniors.

The following educational courses are presented:

Education 1, Psychology for Women.
Education 2, General Methods and School Management.
Education 3, History of Education.
Education 1a, Special Methods in Home Economics.
Education 3a, Practice Teaching.

For the men in training as teachers of agriculture, the following courses are given:

Education 4, Psychology and Vocational Guidance.
Education 5, General Methods and Rural Sociology.
Education 6, Special Methods in Teaching Agriculture.
Education 6a, Practice Teaching.

The department has the following employees:

W. H. French, Director.
E. Lynn Grover, Associate Professor.
Branson A. Walpole, Assistant Professor.
Josephine Hart, Assistant Professor.
Emma Garrison, Assistant Professor.

During the year we have trained sixty-two (62) young women as teachers of home economics and fifty-three (53) young men as teachers of agriculture. The remaining members of the classes were made up of juniors who will be in training next year.

For the practice teaching, we make use of the young women in the East Lansing high school for home economics, and of the young men in the same school for the agriculture. In addition to that, we have taught the subject of home economics in the Haslett Consolidated School under the supervision of our critic teachers, the instruction being given by student teachers. This experiment has proved to be very satisfactory both to the public school at Haslett and to the Teacher Training Department, and we are planning to continue this work for next year.

Of the young men trained for teaching agriculture, all except four or five have already been employed, and will be engaged for this important work for the next school year; and of the young women, all except six are now located in the home economics departments of the public schools of this State. It should be stated here, I think, that Michigan Agricultural College is now providing over fifty per cent of the teachers of home economics of the State and is providing all of the teachers of agriculture.

We feel there are a number of problems yet to be solved in connection with this matter of teacher training. One is in connection with the practice house and the other is concerning the development of a Smith-Hughes school in the East Lansing high school—that is, the instruction given in home economics and in agriculture, be recognized as Smith-Hughes Departments. This is a matter for the consideration of both the State Board of Vocational Education and the Federal Board.

Respectfully submitted,
W. H. FRENCH,
Director Vocational Teacher Training.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DIVISION OF VETERINARY SCIENCE.

Mr. David Friday, President,
Michigan Agricultural College.

Dear President Friday:

Herewith I present the twelfth Annual Report of the Division of Veterinary Science.

No changes in the personnel of the Veterinary Science Division have occurred during the year just closed. However, the work has been apportioned differently. The Department of Surgery and Clinic has become the Department of Surgery and Medicine and has carried the teaching of Veterinary Medicine. The Department of Medicine and Pharmacology has been discontinued and Dr. Taylor and the pharmacology has been transferred to the Department of Anatomy. The above arrangement has permitted Drs. Taylor and Johnson to give about three-fourths of their time to assistance in the Department of Physiology during the fall and winter terms, and Dr. Taylor about one-half time for the spring term. The above arrangement has made the teaching in the Departments of Surgery and Medicine and Anatomy somewhat strenuous and is not wholly satisfactory.

The Department of Surgery and Medicine has conducted the largest clinic which has obtained since the establishment of the Division which is compared in the following chart:

Year.	Equine.	Bovine.	Ovine.	Suis.	Canine.	Feline.	Aves.	Misc.	Total.	Nature.
1920–21	112	46	120	3	141	5	1	....	428	Med. Amb.
	169	362	4	2	93	9	1	2	642	Surg. Amb.
	29	30	4	5	85	5	92	....	250	Med. Hosp.
	103	79	2	4	176	16	....	1	381	Surg. Hosp.
									1,701	Total.
1921–22	56	86	839	250	88	4	1	1	1,325	Med. Amb.
	103	735	5	1,642	101	11	....	1	2,598	Surg. Amb.
	8	21	5	6	144	7	5	2	198	Med. Hosp.
	137	140	1	12	144	34	2	5	475	Surg. Hosp.
									4,596	Total.

Ths work of the Division has been cheerfully performed and I wish to express my appreciation to the Veterinary faculty for their valued cooperation.

The meeting of the American Veterinary Medical Association at Denver, Colorado, was not attended by any member of our faculty. Drs. Hallman and Hutton, attended only the meetings of the U. S. Live Stock Association and the International Live Stock Show. Various members have attended the meetings of local veterinary associations in Detroit, Adrian, Jackson and Marquette. The annual meeting of the Michigan State Veterinary Medical Association held February 7 and 8, was the best and largest in its history. Again the summer meeting held June 28, 29 and 30, 1922, was the best program, attendance 211, sociability, ever staged in Michigan.

Attempts to increase the student enrollment last year were in a measure successful with eleven freshmen. The total enrollment of freshmen veterinary students has not changed from that recorded in the chart prepared by Dean White of the Ohio State University.

Name of Institution, 1921-22.	First year.	Second year.	Third year.	Fourth year.	Special.	Totals.
Alabama Polytechnic Institute	10	5	14	12	....	41
Colorado Agricultural College	23	13	19	16	1	72
Georgia State Agricultural College	9	5	5	2	....	21
Iowa State Agricultural College	28	17	18	19	6	88
Kansas State Agricultural College	12	10	23	10	4	59
Michigan Agricultural College	11	5	6	6	1	29
New York State Veterinary College (Cornell)	15	13	29	16	4	77
New York State Veterinary College (N. Y. Univ.)	5	1	2	5	....	13
Ohio State University	14	13	24	35	....	86
Ontario Veterinary College (Canada)	13	23	35	19	....	90
University of Pennsylvania	11	5	8	7	....	31
Texas Agricultural and Mechanical College	5	1	2	4	....	12
State College of Washington	7	2	7	6	....	22

Prospects of a larger freshman class for 1922 and 1923 are good. Through the valued co-operation of Hon. J. A. Doelle at one time a member of the State Board of Agriculture and Mr. E. E. Gallup, of the Bureau of Education, the Veterinary course is being brought to the attention of the Michigan boy, a part of our program which heretofore has not been accomplished.

In January, as of the class of 1921, Mr. H. A. Goss was graduated, and June 21, 1922, the following men received the degree of Doctor of Veterinary Medicine:

Mr. R. F. Blatchford,
Mr. Harry Buchman,
Mr. R. E. Hammond,
Mr. P. V. Howard,
Mr. H. A. Weckler.

Of the above men two will enter private practice, one will enter commercial work, one municipal work and one State work.

ANATOMY DEPARTMENT.

The housing condition for work in anatomy has not changed since the erection of the present Surgery and Clinic Building. The buildings are inadequate and of obsolete design and should receive early attention. Teaching methods require museum and laboratory work which under present conditions is impossible to provide.

The work of the department included pharmacology and assistance to the Department of Physiology has been carried on by Drs. Chamberlain, Johnson and Taylor. The chart below shows in part the work done.

Subject.	No. of students.	Credits.	Lectures.	Laboratory.	Total class hours.
Fall:					
Anatomy 1a	20	4	24	72	96
Anatomy 2a	7	7	24	180	204
Anatomy 4	10	4	24	72	96
Poultry 5	5	5	12	48	60
Pharmacology 2	7	5	48	24	72
Pharmacology 4a	6	3	36	....	36
Physiology 1 (Sec. 3 and 4)	50	4	....	96	96
Physiology 1 (Sec. 1, 2, 3, 5, 6)	90	6	....	144	144
Total	195	38	168	636	804
Winter:					
Anatomy 1a	2	4	24	72	96
Anatomy 1b	18	3	12	72	84
Anatomy 2b	7	2	....	72	72
Anatomy 3a	24	4	24	72	96
Poultry Husbandry 5	6	5	24	24	48
Pharmacology 2a	7	2	....	48	48
Pharmacology 4b	5	3	36	....	36
Physiology 1 (Sec. 4, 5, 6)	57	6	....	144	144
Physiology 1 (Sec. 4, 5, 6)	119	7	....	144	144
Total	245	36	120	648	768
Spring:					
Anatomy 1c	13	4	12	108	120
Anatomy 2c	7	2	....	72	72
Anatomy 3b	16	4	24	72	96
Pharmacology 1	8	5	48	24	72
Pharmacology 4c	6	3	36	....	36
Physiology 1 (Sec. 4)	14	2	....	48	48
Total	64	20	120	324	544
Grand total	404	94	408	1,608	2,016

The chart is self explanatory. Bearing in mind that practically all irregularities of classification of students taking work in the Veterinary Divison find adjustment in this department and involve many hours of extra work on the part of the instruction staff.

Respectfully submitted,
F. W. CHAMBERLAIN,
Acting Dean.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF ANIMAL PATHOLOGY.

President David Friday,
Michigan Agricultural College.
Dear Mr. President:

I herewith submit report of the Department of Animal Pathology for the year ending June 30th, 1922.

The instruction work for the year was as follows:

Pathology 2a, Fall term, 5 hours per week, 7 students.
Pathology 1, Winter term, 10 hours per week, 6 students.
Pathology 2b, Spring term, 4 hours per week, 6 students.
Pathology 3, Spring term, 5 hours per week, 6 students.
Poultry Husb. 4, Spring term, 3 hours per week, 7 students.
Veterinary science, short course, winter term, 24 lectures, 32 students.

During the year the department has held autopsies on 154 animals and has made examinations of specimens from 87 diseased animals sent in for examination by farmers and veterinarians.

The autopsies are as follows:

Four horses, nineteen cattle, eleven sheep, twenty-two swine, three dogs, eighty-seven chickens, one fox, two rabbits, one bear, one reindeer, one badger, one white rat and one eagle.

Among these are:
Acute interstitial nephritis, foal 4.
Acute gastro-intestinal intoxication, calves 2.
Endometritis, cow 1.
Lobar pneumonia, cow 2.
Necrotic pneumonia, cow 1.
Pyemia, cow 1.
Sarcomatosis, cow 2.
Traumatic pericarditis, cow 1.
Tuberculosis, cow 6.
Acute gastro-intestinal intoxication, sheep 1.
Hemorrhagic septicemia, sheep 3.
Intestinal helminthiasis, sheep 1.
Necrotic pneumonia, sheep 1.
Peri aortic hematoma, sheep 1.
Pulmonary congestion, sheep 1.
Rupture, posterior vena cava, sheep 1.
Septic metritis, sheep 1.
Acute gastro-intestinal intoxication, swine 1.
Acute lobar pneumonia, swine 1.
Acute tympanitis, swine 1.
Hemorrhagic gastritis, swine 1.
Hog cholera, swine 3.

Prolapse of rectum, swine 1.
Pseudo leukemia, swine 1.
Rachitis, swine 1.
Rarefying ostitis, swine 1.
Rupture of intestine, swine 1.
Septicemia, swine 1.
Thrombosis, swine 1.
Ulcerative enteritis, swine 1.
Acute fibrinous pericarditis, fowl 1.
Acute intestinal intoxication, fowl 1.
Acute lobar pneumonia, fowl 1.
Abdominal hemorrhage, fowl 1.
Avian diphtheria, fowl 4.
Botulism, fowl 2.
Catarrhal enteritis, fowl 2.
Coccidiosis, fowl 9.
Conjunctivitis, fowl 1.
Contagious epithelioma, fowl 2.
Fibroma, fowl 2.
Intestinal helminthiasis, fowl 8.
Pediculosis, fowl 1.
Sarcoma, fowl 1.
Tuberculosis, fowl 25.
Chronic colitis, dog 1.
Intussusception, colon, dog 1.
Rupture, right ventrical, dog 1.
Septicemia, fox 1.
Generalized peritonitis, rabbit 1.
Pyometra, rabbit 1.
Hemorrhagic duodemitis, bear 1.
Acute gastro-intestinal intoxication, reindeer 1.
Acute lobar pneumonia, badger 1.
Tuberculosis, eagle 1.

Specimens from diseased animals sent to the laboratory by farmers and veterinarians for examination are as follows:

Two horses, twenty-two cows, six sheep, ten swine, nineteen dogs, two cats, twenty-five fowls, one rabbit.

Among these are recorded:

Fibroma, horse 1.
Acute intestinal intoxication, sheep 1.
Goitre, sheep 1.
Hematoma, liver, sheep 1.
Intestinal helminthiasis, sheep 1.
Nodular disease, sheep 3.
Abscess, carpal region, cow 1.
Actinomycosis, cow 1.
Acute parenchymatous nephritis, cow 1.
Arthritis, cow 1.
Chronic enteritis, cow 1.
Chronic pyometra, cow 3.

Fibroma, cow 1.
Hematoma, cow 1.
Hemorrahgic enteritis, cow 1.
Papillary epithelioma, cow 1.
Sarcoma, cow 1.
Suppurative hepatitis, cow 2.
Tuberculosis, cow 1.
Alveolar sarcoma, dog 1.
Anemic infarct, dog 1.
Demodex mange, dog 6.
Eczema, dog 1.
Fatty infiltration liver, dog 1.
Intestinal helminthiasis, dog 1.
Papillary epithelioma, dog 1.
Sarcoptic mange, dog 1.
Coccidiosis, fowl 1.
Contagious epithelioma, fowl 2.
Cranial abscess, fowl 1.
Fatty degeneration liver, fowl 1.
Hematoma, fowl 1.
Infectious entero-hepatitis, fowl 4.
Intestinal helminthiasis, fowl 1.
Osteoporosis, fowl 1.
Ruptured oviduct, fowl 1.
Sarcomatosis, fowl 1.
Tuberculosis, fowl 3.
Erythema, swine 1.
Icterus, swine 1.
Sarcomatosis, swine 1.
Sub. lumbar abscess, swine 1.
Suppurative hepatitis, swine 1.
Urticaria, swine 1.
Sarcoptic mange, cat 1.
Symbiotic mange, rabbit 1.

Dr. Runnels, in addition to his teaching, autopsy work and examination of specimens from diseased animals, has served as Secretary of the Michigan State Veterinary Medical Association during the last year. This work demands a considerable part of his time but it is the writer's opinion that such time is well spent in that it brings the veterinary profession of the State into closer touch with the College than would be the case otherwise. Further, a part of his time has been devoted to the preparation of specimens for the pathological museum and a few trips into the State on extension work have been made by him.

A large part of the writer's time has been devoted to a continuation of his studies on the diseases of the reproductive organs of cattle and to the study of the evolution and involution of the uterus of the cow during and subsequent to pregnancy. A report of this work may be found in the department's report to the Director of the Experiment Station.

Respectfully submitted,
E. T. HALLMAN,
Associate Prof. of Animal Pathology.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF SURGERY AND MEDICINE.

President David Friday,
Michigan Agricultural College.
Dear President Friday:

I hereby submit my fifth annual report of the Department of Surgery and Medicine for the fiscal year ending June 30th, 1922. Heretofore my report has been submitted under the name of Surgery and Clinic Department. In July, 1921, the State Board of Agriculture placed the Department of Medicine in the department of Surgery and Clinic and changed the name to the Department of Surgery and Medicine.

The recitation and laboratory work of the department has been handled entirely by Dr. Sales and myself. The ambulatory clinic has been handled by Dr. McKercher, Dr. Sales and myself. In addition to the regular work of the department we have given instruction in Veterinary Science 2a, 2b and 2c which is elective for Agricultural and Forestry courses.

The total number of medical and surgical hospital cases treated during the school year 1921-22 was 673, an increase of 42 cases over the previous year.

The total number of ambulatory cases treated was 3923, an increase of 2854 cases over the school year 1920-21. The total number of animals treated by the department during the school year 1921-22 including both ambulatory and hospital clinic was 4596, an increase of 2896 cases over the school year 1920-21. Out of this number 304 were horses, 982 were cattle, 850 were sheep, 1910 were hogs, 477 were dogs, 56 were cats, 8 were chickens, 2 bears, 2 turkeys, 2 rabbits, 1 goat, 1 eagle and 1 mule.

The number of cases treated by the department and the large variety of material available for instruction purposes has been the largest and most satisfactory in the history of the clinic.

Respectfully submitted,
JOHN P. HUTTON,
Associate Professor of Surgery and Medicine.

East Lansing, Michigan, June 30, 1921.

A tabulated report of the instruction work for the school year 1921-1922 is given in the following table.

Subject.	Fall term.		Winter term.		Spring term.	
	Recitation hours per week.	Laboratory hours per week.	Recitation hours per week.	Laboratory hours per week.	Recitation hours per week.	Laboratory hours per week.
Surgery 1	4	4				
Surgery 2					2	
Surgery 3	4	4				
Clinic 4a				15		
Clinic 4b						15
Clinic 4c		15				
Clinic 4d				15		
Clinic 4e						15
Surgery 5			3			
Surgery 6			4			
Medicine 1	4					
Medicine 3a			5			
Medicine 3b					4	
Medicine 4a			5			
Medicine 4b					4	
Zootechnics 1			2	2		
Veterinary Science 2a	5					
Veterinary Science 2b			5			
Veterinary Science 2c					5	
Total	17	23	24	32	15	30

A tabulated report of the hospital clinic for large and small animals treated from July 1, 1921, to June 30, 1922.

Medical cases.	Horses.	Cattle.	Sheep.	Hogs.	Dogs.	Cats.	Chickens.	Other.
Arthritis, acute		1						
Atony of fore-stomach		1						
Avian diphtheria							3	
Boarded		2			8			
Bursitis					1			
Bronchitis					2			
Castration, simple					1	2		
Chorea					3			
Colic, flatulent	1	1						
Compresson, spinal cord	1							
Concussion of brain					2			
Constipation					1			
Conjunctivitis	1	1			1			
Cow pox		3						
Dermatitis (pustular)				1				
Distemper					53			
Eczema					5			
Emphysema (pulmonary)	1							
Flees					12			
Forage poisoning		1						
Gastritis				1	13	1		
Gastro-enteritis				1				
Gastro, intestinal catarrh of sucklings		2						
Gastro-intestinal catarrh of horse	2							
Gastric tympany		1						
Helminthiasis			3		11			
Hemorrhagic septicemia			2					
Hepatitis, acute					1			
Intussusception, intestinal					1			
Laryngitis						1		
Mange, demodex					10			
Mange, symbiotes auriculum								rabbit
Mange, sarcops	1				11	3		
No diagnosis				1	1			
Pneumonia		2		1				
Rachnitis				1				
Ringworm					1			
Roup							2	
Stomatitis					2			
Tetanus	1							
Traumatic pericarditis		1						
Tuberculosis		5						eagle
Utricia					1			
Total	8	21	5	6	144	7	5	2

Surgical cases.	Horses.	Cattle.	Sheep.	Hogs.	Dogs.	Cats.	Chickens.	Other.
Abortion	1	1						
Abscess		4					1	
Actinomycosis		3						
Air under skin								turkey
Amputation of tail					8			
Arthritis suppurative								mule
Atrophy of shoulder muscle	1							
Bursitis, chronic	1							
Canker	1							
Castration, simple	5	5		1	6	15		goat
Cataract					1			
Cervicitis		3						
Collar gall	3							
Contusion	32				4	1		
Cryptorchid castration	1							
Dental fistula	1							
Destroyed	1				4	6		
Distemper vaccination					1			
Distokia					1			
Ear trimming					4			
Estrum		1			1			
Examination fór pregnancy		11						
Excision of eye					1			
Edema		1						
Fistula	1				1			
Fistula, bone	2							
Fistula, sinus	1							
Fistula, withers	7							
Fracture of femur					1			
Fracture of humerus					1			
Fracture of radius					1			
Fracture of vertebra					1			
Goitre					3			
Gonitis	2							
Hematoma		4			3			
Hernia, scrotal				4				
Hernia, umbilical	1				1			
Hygroma		1						
Hydrocele	1							
Impaction of crop							1	turkey
Keratitis					4			
Laminitis	2							
Mammitis		1						
Metritis		4						
Mycosis					1			
Navicular disease	4							
Otitis					10	1		
Ovariotomy	2				65	11		
Panaritum		2						
Paraplegia				1				
Penetrating street nail	1							
Periodic opthalmia	2							
Pododermatitis		1						
Polypus, nasal	1							
Prolapse, rectum				3	1			
Prolapse, vagina			1					
Pyometra		3						rabbit
Quarter crack	1							
Quittor	3							
Retained placenta		15						
Roarer	4							
Rupture of intestines				1				

Surgical cases.	Horses.	Cattle.	Sheep.	Hogs.	Dogs.	Cats.	Chickens.	Other.
Scratches	3							
Sharp teeth	22							
Spavin bone	4							
Spinal injury		1						
Sterility		11						
Sweeny	1							
Teeth, extraction	3				1			
Trimming toenails					4			
Tuberculin test		67						
Tumors	2	1		2	3	1		
Wound, caustic					1			
Wound, contused	1							
Wound, gunshot					2			
Wound, incised					5			
Wound, lacerated	8				4			
Wound, puncture	10							
Total	137	140	1	12	144	34	2	5

A tabulated report of the ambulatory clinic for large and small animals treated from July 1, 1921 to June 30, 1922.

Medical cases.	Horses.	Cattle.	Sheep.	Hogs.	Dogs.	Cats.	Chickens.	Other.
Actinomycosis		2						
Atomy of fore-stomach		6						
Alopecia					1			
Arthritis	1	3						
Azoturia	4							
Blackleg		2						
Bronchitis	2							
Colic, spasmodic	12							
Colic, flatulent	3							
Colic, impaction	10							
Cow pox		1						
Constipation					7			
Distemper					24			
Dermatitis					2			
Emphysema, chronic alveolar.	1							
Epilepsy					2			
Flees					5	1		
Forage poisoning		3						
Gastro - intestinal catarrh, sucklings		7						
Gastro tympany		3						
Gastro-intestinal catarrh	2				7			
Helminthiasis, intestinal	1				26	1		
Hog cholera				84				
Hemorrhagic septicemia		18						
Heat stroke	1							
Impaction of rumen		20						
Intestinal catarrh					1			
Intestinal intoxication				1				
Influenza	6							
Indigestion								bear
Laryngitis	1							
Lead poisoning		1						
Lymphangitis	1							
Metiritis		6						
Mange sarcops					1	2		
Mange, demodex					7			
No diagnosis	1		1					
Opthalmia, contagious		1						
Pneumonia, verminous			1	12				
Pneumonia	3	2						
Periodic ophthalmia	1							
Ringworm		4						
Rickets				1	1			
Rhinitis	1							
Stomatis	1	1			1			
Strangles	1							
Stomach worm treatment			836					
Septicemia		1						
Stomach worms			1					
Strychnine poisoning					3			
Traumatic pericarditis		3						
Tuberculosis		1					1	
Traumatic gastritis		1						
Treatment for intestinal parasites				152				
Tetanus	3							
Total	56	86	839	250	88	4	1	1

Surgical cases.	Horses.	Cattle.	Sheep.	Hogs.	Dogs.	Cats.	Chickens.	Other.
Abortion		4						
Abscess	3	12		3	2			
Amputation of tail					3			
Blackleg vaccination		39						
Corns	1							
Crural paralysis	1							
Contusion	3	8			6	2		
Choke		1						
Castration, simple	2	8		69	4	8		
Canker	1							
Contraction of flexor tendon	1							
Cervicitis		4						
Conjunctivitis					2			
Dystokia	1	9	1	1	1			
Dehorning		5						
Distemper vaccination					7			
Ear trimming					14			
Examination for pregnancy		3						
Enteritis						1		bear
Emphyema of maxillary sinus	1							
Fracture of illum		2			2			
Fracture of femur				1	1			
Fracture of cervical vertebrae	1							
Fracture of pelvis		1						
Fracture of maxilla	1							
Fracture of tibia					3			
Fracture of first phalanx	1							
Fistula bone	1	1						
Goitre					1			
Nygroma		1						
Hog cholera vaccination				1,563				
Hemorrhagic sept. vaccination		110						
Hip lameness	1							
Hematoma	2							
Killed by lightning	1							
Keratoma		1						
Keratitis	1	1			2			
Laminitis	3							
Luxation of hip joint					1			
Mastitis	2	17		2				
Navicular disease	1							
Naval hemorrhage		1						
Otorrhea					1			
Ovariotomy					31			
Paraplegia		2			3			
Panaritum		7						
Paraphymosis			1					
Parturient paresis		8						
Prolapse of vagina		1	3	1				
Phlegmon		1						
Pervous urachus	2							
Pododermatitis	1	3						
Paralysis of bladder					1			
Physical examination		35						
Poll evil	1							
Prolapse of uterus					1			
Quarter crack	2							
Quittor	2							
Retained placenta	1	9						
Radial paralysis	2							
Rupture of tendon achilles		1						

Surgical cases.	Horses.	Cattle.	Sheep.	Hogs.	Dogs.	Cats.	Chickens.	Other.
Sterility		8						
Sesamoiditis	1							
Scratches	1							
Sharp teeth	9							
Shoe boil	1							
Spavin, bone	2							
Tumor	2	3		2	1			
Thrush	9							
Teat stricture		11						
Tuberculin test		418						
Teat fistula		2						
Tendonitis	3							
Ulcer		1						
Vaginitis		1			1			
Wound, caustic					1			
Wound, puncture	20	3			1			
Wound, incised	1							
Wound, lacerated	8	3			9			
Wound, contused	4				1			
Wound, gunshot					1			
Wolf tooth extraction	2							
Total	103	735	5	1,642	101	11		1

REPORT OF THE REGISTRAR.

President David Friday,
Michigan Agricultural College.

Dear Sir:

I have the honor to present the following report of the Registrar's Office for the year ending June 30, 1922:

In the regular college courses the enrollment for the year is as follows:

Agriculture and Forestry	551	
Engineering	543	
Home Economics	432	
Applied Science	122	
Veterinary	32	
Total		1,680
Summer School	367	
Graduate Course	13	
Total		380

SHORT COURSES.

Two-year sixteen weeks' course in Agriculture	100	
Two-year eight weeks' course in Agriculture	48	
Eight-weeks' course in Horticulture	35	
Eight-weeks' course in Farm Engineering	7	
Eight-weeks' course in Dairy Production	32	
Eight-weeks' course in Dairy Manufacture	32	
Eight-weeks' course in Farm Business	5	
Four-weeks' course in Poultry Husbandry	24	
Four-weeks' course in Ice Cream Making	21	
Two-weeks' course in Cow Testing and Dairy Barn Management	50	
Four-weeks' course in Truck and Tractor	94	
Special Courses	6	
Total		454
Vocational Guidance School		218
Total in all Courses		2,732
Names repeated		272
Net total		2,460

ENROLLMENT BY TERMS.

Course.	Fall.	Winter.	Spring.	Summer.
Agriculture and Forestry	532	532	476	160
Engineering	521	484	463	87
Home Economics	421	391	371	96
Applied Science	115	102	94	1
Veterinary Medicine	30	31	29	4
Graduate	10	13	12	
Rural Teachers				19
Totals	1,629	1,553	1,445	367

ENROLLMENT BY CLASSES.

	Agr.	For.	Eng.	H. E.	Sci.	Vet.	Total.
Graduates	13						13
Seniors	90	21	77	75		5	268
Juniors	108	20	110	83		7	328
Sophomores	103	18	140	94	24	7	386
Freshmen	187		214	177	98	12	688
Special Students	4		2	3		1	10
Summer Session	135	25	87	96	1	4	348
Rural Teachers							19
Totals	640	84	630	528	123	36	2,060

GEOGRAPHICAL DISTRIBUTION OF STUDENTS.

Armenia	1	Maryland	1
Asia Minor	2	Massachusetts	1
California	5	Michigan	1,732
Canada	3	Minnesota	1
China	2	Missouri	1
Colorado	1	New Jersey	6
Connecticut	2	New Mexico	1
Delaware	2	New York	19
District of Columbia	2	Ohio	28
Egypt	2	Oklahoma	1
England	1	Pennsylvania	8
Florida	1	Philippine Islands	1
Illinois	24	Turkey	2
Indiana	4	Vermont	1
Iowa	3	Virginia	1
Japan	1	West Virginia	1
Kentucky	1	Wisconsin	3

STUDENTS ENTERING DURING THE YEAR 1921–1922.

Number Enrolled.

Agricultural and Forestry Course	184	
Engineering Course	217	
Home Economics Course	188	
Applied Science Course	87	
Veterinary Medicine	14	
Graduate Students	4	
Total		694

Preparation.

Graduates of Accredited High Schools	...	
High School Credits and Examinations	...	
Credits from Other Colleges	65	
Federal Preparatory	23	
Total		88

DEGREES GRANTED JUNE 21, 1922.

BACHELOR OF SCIENCE.

a, Agriculture; e, Engineering; h, Home Economics; f, Forestry.

Jay Charles Ackerman, e.
Fred Philip Adolph, a.
Harvey Arthur Anderson, e..
Margaret Louise Andrews, h.
Lloyd Chester Atkins, a.
Howard Chapman Bacon, e.
John Searls Bailey, a.
Gerald Weston Rexene Baldwin, a.
Francis Norman Bateman, e.
Guy Rix Bennett, e.
Vera Pauline Benore, h.
Walter Sydney Bersey, e.
Ellsworth Iola Besemer, a.
Herman Henry Bickel, e.
Ruth Eleanor Biebesheimer, h.
Harold Russell Bigford, f.
Roger William Billings, f.
Fred Horace Black, a.
George Dewey Blair, f.
William Barnard Blanchard, a.
Richard S. Boonstra, e.
Helen Leone Booth, h.
John Bos, a.
Nellie Margaret Bowerman, h.
Anthony Joseph Brendel, a.
Carl Merwin Brown, e.
Emerson Christian Brown, a.
Irene Jessie Brownell, h.
Charles Edward Brumm, e.
Nannie Musetta Bunker, h.
Panos Demetrius Caldis, a.
Clara Marion Carbine, h.
Miriam Clark Carpenter, h.
Lewis Jarvis Carter, a.
Francis Trevelyn Carver, e.
Raymond McCallum Clark, a.
Edward Davis Clifford, f.
Harold Malcolm Coburn, e.
Lucy Ellura Cole, h.
Effie Marie Cook, h.
Harry William Coon, e.
James Fuller Crum, a.
Emma Loretta Culver, h.
Glenn Raymond Cummings, e.
John Joseph Dalton, a.
John Bolivar Davidson, e.
Samuel Beard DeMerrell, e.
Daniel DenUyl, f.
Karl Dressel, f.
Donald West Durfee, e.
Thelma Maurine Dutt, h.
Anton John Dvylis, a.
Claud Robert Erickson, e.
DeGay Ernst, e.
Beryl Evens, n.
Belle Julia Farley, h.
Max English Farr, a.
Stewart Martin Farr, a.
Clifford Searl Fitch, e.
Harold Lozzel Fleming, e.
Donald Whalley Floten, e.
Arthur Wayne Flucke, f.
Dorothy Grace Foster, h.
Walter John Foster, a.
Grace Edna Fox, h.
Forrest Judson Freeman, e.
Mildred Freeman, h.
Ivan Foster French, e.
Noel Vincent Fullen, e.
Bernard Farrell Gaffney, a.
Gerald Glenn Geisler, a.
Paul Dillingham Gibson, a.
Thoburn Earl Gibson, a.
Mary Ann Gilchrist, h.
Wayne A. Gingrich, e.
Leo Benjamin Grant, e.
John Milo Donald Gray, f.
Esther Pauline Grettenberger, h.
Harry L. Grill, e.
Lillian Ruth Grimm, h.

Marguerite Esther Gunn, h.
Clifford Walter Gustafson, e.
Thelma Elizbaeth Haite, h.
Merlin J. Hamilton, a.
Olevia B. Harmon, h.
Lyle Edward Harper, a.
Irene A. Hartman, h.
George Alexander Harvey, e.
Daniel Edward Hasley, a.
Allie Lewis Hatovsky, e.
Floyd Mark Hazel, a.
Charles Clarence Higbie, a.
Fred Mix Hill, e.
Kathaleen Hill, h.
James Peter Hoekzema, a.
John Henry Hohnke, e.
Clarence Shaw Hood, f.
Harriet Beth Hooper, h.
Cyril Minard Hough, e.
Neva Blanche Howard, h.
Robert Edgar Houston, e.
Wayne R. Hoyt, a.
Merrill Van Hunter, e.
Emory E. Huyck, a.
Murray Ward Jacklin, e.
Arno Hallock Johnson, e.
Leo Earl Johnson, a.
Arnold Victor Kalm, e.
Wayne Frederick Kaltenbach, a.
Leroy Frederick Keely, e.
Gladys Marmaduke Kellogg, h.
Mildred Clare Ketcham, h.
Frank Madison Keyt, a.
Jennie Ruth Kintigh, h.
Clara Louise Kling, h.
Alice Ella Kohler, h.
Harold Koopman, e.
Max Axel Krabbe, e.
Mina Oril Lawrence, h.
Ruby Miriam Lee, a.
Martin Lefler, a.
Dorothy Dodd Lepper, h.
Ralph Jay MacVean, a.
Anah Alfaretta McCool, h.
Ione Whitmore McKillen, h.
Alice Emilie McKnight, h.
Franklin Jay McNall, e.
Ralph Paul Maloney, f.
Florence Jean Manning, h.
Ernest Lawrence Markley, e.
Irene Christine Marthen, h.
Carl Frederick Martin, f.
Julius William Marx, e.
Edward Isaac Matson, e.
Ottilie Louise Matthes, h.
Burton Clifford Mellencamp, a.
Ellwood Manning Nelson, a.
LaFern Viola Merrill, h.
Allen Frank Monroe, f.
Theodore Davie Moss, e.
Victor Moore Nagler, e.
Thomas Jerome Navarre, e.
Morris Alfred Nelson, e.
Ruth Emma Newman, h.
Donald Fred Nickel, e.
Ubold John Noblet, f.
Edward Payson North, e.
Russell Rawson Palmer, a.
Esther Mae Parker, h.
Helen Dorothy Parker, h.
Ralph Alexander Paton, a.
Samuel Hadley Patterson, a.
Martha Helen Perry, h.
George Robert Phillips, f.
Ronald Stewart Pocklington, a.
Thomas Baird Poole, a.
Lowry Oliver Porter, a.
Bernard Remi Proulx, a.
Harold George Putnam, a.
Stanley Shugarts Radford, e.
Mary Emily Ranney, h.
Edna Ray, h.
Reid Leicester Rayner, e.
Fanny Elina Rentola, h.
Percy Lumon Rice, e.
Donald George Robinson, e.
Ruth Merrill Rowland, h.
Bertha Sanborn, h.
Ethel Roxana Sayer, a.
Arthur Rashleigh Schubert, a.
George Francis Schulgen, e.
Eileen Janet Seble, h.
Herman Emanuel Segelin, a.
Marion Lucile Shane, h.
Lloyd Arthur Sheffield, a.
Warren Karl Slaughter, a.
Marc Humphery Small, e.
Arno David Smith, a.
Ezekiel Jay Smith, e.
Forrest Allen Smith, a.
William James Smith, a.
Rufus Walter Snyder, e.
James Glarum Stelzer, e.
Murdo Dwight Stitt, e.
Owen Stricklen, a.
Floyd Harrison Struble, f.
Dorothy Alice Sweeney, h.
William James Sweetman, a.
Helen Irma Takken, h.
Frank Hutchins Thomas, a.
Margaret Barr Thomson, h.
Lloyd Massena Thurston, a.
George Emmons Tichenor, a.
Margaret Marion Tower, h.
Marie Antoinette Trevithick, h.
Harriet Judith Tumans, h.
Mattie Julia Vincent, h.
Royal J. Vincent, e.
William Upsall Vinton, e.
Alice Delphine Voorheis, h.
Glenn Irving Voorheis, e.
John Dewey Walker, a.
Catharine Elizabeth Watkins, h.
Charles A. Weckler, e.
James Robert Wellman, e.
Roy James Werdon, a.
Ruthford Henry Westveld, f.
Flora Ida Wettlaufer, h.
Victor Ira Whittemore, a.
Harold N. Wilhelm, e.
Dorothy Ethel Wilson, h.
George Edwin Wilson, a.
James Dean Wilson, a.
William Ralph Wilson, e.
Cheryl Windes, h.
Joseph Reginald Witwer, f.
Herbert Lee Wright, a.
Ward Lavere Wylie, e.
Dorothy Martha Yakeley, h.
Sidney Howe Yarnell, a.
Manley Elijah Young, a.

DOCTORS OF VETERINARY MEDICINE.

Robert Francis Blatchford.
Harry Buchman.
Ralph Elmer Hammond.
Paul Veloice Howard.
Harry A. Weckler.

MASTERS OF SCIENCE.

Hung Chun Chang.
Christos Demetrios Christoulias.
Sarkis Garabed Der Sarkissian.
Otto Herman Friedemann.
Romine Carl Stoll.
Grosvenor Ward Putnam.

MASTERS OF AGRICULTURE.

Elton Brainard Hill.
Eldon Eugene Down.
Stanley J. Brownell.

ELECTRICAL ENGINEER.

Emerson Allen Armstrong.

DOCTOR OF AGRICULTURE.

Robert Sidey Shaw.

DEGREES GRANTED AUGUST 17, 1921.

MASTER OF SCIENCE.

Hohei Funayama.

DEGREES GRANTED JANUARY 17, 1922.

BACHELOR OF SCIENCE.

Henry Lockyer Broan, e.
Willis Campbell, a.
Myron Van Gleason, a.
Wayne VanEman Palm, a.
Floyd Alonzo Prentice, a.
James McKinley Gorsline, a.
Marie Frances Corcoran, h.
Dorothy Margaret Thorburn, h.
Leon Ward Schroyer, e.
Marshall Gideon Draper, e.

DOCTOR OF VETERINARY MEDICINE.

Henry Ahnefeldt Goss.

SUMMARY OF DEGREES GRANTED DURING THE YEAR 1921-22.

BACHELOR OF SCIENCE.

Agricultural Course	74	
Engineering Course	73	
Home Economics Course	68	
Forestry Course	17	
Total		232
Doctor of Veterinary Medicine	6	
Master of Science	7	
Professional Degrees	4	
Honorary Degree	1	
		18
Total		250

Respectfully submitted,
ELIDA YAKELY,
Registrar.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE LIBRARIAN.

President David Friday,
Michigan Agricultural College.
Dear Sir:

I have the honor to present the following report on the Library for the year ending June 30, 1922:

During the year additions have been made to the library as follows: Of bound volumes, 840. Of this number 387 were added by purchase, 245 by binding and 198 by gift. Of unbound volumes and pamphlets, 74 were received for which acknowledgment was made.

For gifts of bound volumes we are indebted as follows:

American Railway Assn., 1
Boyd, J. 1
Calumet Baking Powder Co., 1
Cotter, A. 1
Cole and Geddes, 1
Colorado, 1
Doubleday, Page & Co., 1
Farm Mortgage Bankers' Assn., 1
Farm Journal, 1
Giltner, Dr. Ward, 1
Gardner, Victor R. 1
Girl Scouts, 1
Home Economics Dept. 82
Iowa, 1
Illinois, 4
Kansas, 1
Lowe, E. P. 1
Massachusetts, 1
Maryland, 2
Michigan, 38
New York, 23
N. Y. Life Insurance Co., 1
Nebraska, 1
National Agricultural Conference, 1
Successful Farming, 1
Schutz, C. F. 1
Smithsonian Institution, 3
University of Michigan, 1
United States, 4
Vermont, 1
Waltham School for Nurses, 1
Yale University, 1
Unknown, 4

The College library subscribes to 229 periodicals, and the Experiment Station to 43, all of which are filed in the reading room. In addition to our paid subscriptions, we receive a number of publications either as gifts from publishers, or in exchange for our own publications. The list follows:

Aberdeen Angus Journal.
Academy of Natural Sciences, Phila., Proceedings.
Agricultural Gazette of Canada.
Agricultural Gazette of N. S. Wales.
Agricultural Review.
Allegan Gazette.
American Bankers' Assn., Journal.
American Farming.
American Food Journal.
American Fruit Grower.
American Miller.
American Philosophical Society, Proceedings.
American Poultry Advocate.
American School Board Journal.
American Seedsman.
American Sheepbreeder.
American Steel and Wire Co., Crop reports.
American Swineherd.
Australasian.
Australian Museum, Records.
Bean Bag.
Belding Banner.
Berkshire World.
Better Business.
Better Fruit.
Board of Agriculture, (London) Journal.
Board of Agriculture, (London) Leaflets.
Boletin de Agriculture, Sao Paulo.
Boston Museum of Fine Arts, Bulletin.
Brooklyn Botanic Garden, Leaflets.
Brooklyn Botanic Garden, Record.
Buick bulletin.
California Agriculture Dept., Monthly bulletin.
California Acad. of Science, Proceedings.
California University, Publications in Agricultural Science.
California University, Publications in Zoology.
Canadian Horticulturalist.
Chester White Journal.
Cloverland Magazine.
Commerce Reports, U. S.
Congressional Record.
Constitutional Review.
Dairy Record.
Dakota Farmer.
Detroit Educational Bulletin.

DuPont Magazine.
Duroc Bulletin.
East Lansing Community Life.
Eaton Rapids Journal.
Electric Traction.
Electrical Trade.
Elgin Dairy Report.
Farm and Fireside.
Farm Journal.
Farmers' Advocate.
Farmington Enterprise.
Field Illustrated and System on the Farm.
Florida Entomologist.
Flour and Feed.
Flower Grower.
Fruit Belt.
Grand Rapids Public Library, Bulletin.
Guaranty Trust Co., Letters.
Hawaiian Forester.
Highway Magazine.
Hoard's Dairyman.
Holcad.
Il Giornale d'Italia Agricole.
Illuminating Engineer.
India Agrl. Research Institute, Pusa. Bulletins.
India Agrl. Research Institute, Pusa. Agrl. Journal of India.
India Agrl. Research Institute, Pusa. Memoirs, Bacteriologie.
India Agrl. Research Institute, Pusa. Memoirs, Botanical series.
India Agrl. Research Institute, Pusa. Memoirs, Chemical series.
India Agrl. Research Institute, Pusa. Memoirs, Entomological series.
Indiana Farmers' Guide.
Indian's Friend.
Indicator.
Ingham County News.
International Institute of Agriculture, Annuaire International de Ststique Agricole.
International Institute of Agriculture, Bureau of Economic and Social Intelligence.
International Institute of Agriculture, Bureau of Statistics.
International Institute of Agriculture, Bureau of Documentary Leaflets.
International Institute of Agriculture, Bulletin of Agrl. Intelligence of Plant Diseases.
Investment Bankers' Assn. of America, Bulletins.
James' Barn Magazine.
Japan Review.
Jersey Bulletin.
Johns Hopkins Univ. Circulars,
Johns Hopkins Univ. Studies.
Jonesville Independent.
Journal of Agrl. Research.

Journal of Agriculture, Victoria.
Journal of Agriculture and Horticulture.
Journal of the College of Science, Imperial Univ., Sapporo, Japan.
Journal of the College of Science, Imperial Univ., Tokio, Japan.
Journal of the Dept. of Agriculture, S. Australia.
Live Stock Report, (Clay Robinson.)
Market Growers' Journal.
The Market Reporter.
Message of the East.
Mexican Review.
Miani Conservancy Bulletin.
Michigan Business Farmer.
Michigan Farmer.
Michigan History Magazine.
Michigan Library Bulletin.
Michigan Patron.
Midland Naturalist.
Midland Sun.
Missouri Botanical Gardens, Annals.
Moderator-Topics.
Monthly Bulletin, State Commission of Hort., Sacramento, Cal.
Monthly Crop Reporter.
National Education Association, Bulletin.
National Farmer.
National Grange Monthly.
National Provisioner.
National Stockman and Farmer.
National Weather and Crop Bulletin.
Nature Study Review.
N. Y. Botanical Garden, Bulletin.
N. Y. Meteorology, Drapers Hourly Readings.
News Bulletin.
Official Gazette, U. S. Patent Office.
Ohio Farmer.
O. K. Poultry Journal.
Open Road.
Orange Judd Farmer.
Pacific Dairy Review.
Pan-American Union, Bulletin.
Panama Canal Record.
Philippine Agrl. Review.
Philippine Agriculturalist and Forester.
Power Farming.
Practical Farmer.
Prairie Farmer.
Professional Engineer.
Progressive Farmer.
Public Health Reports.
Reclamation Record.
Reliable Poultry Journal.
Rhodesia Agricultural Journal.

Rice Institute Pamphlet.
Rockefeller Institute for Medical Research, Studies.
The Rotarian.
Russian Information Bureau in the U. S., Bulletin.
Science and Industry. (Australia.)
Seed World.
Shorthorn in America.
Smithsonian Institution, U. S. Nat. Museum, Bulletin.
Smithsonian Institution, U. S. Nat. Herbarium, Bulletin.
Smithsonian Institution, Misc. Collections.
Successful Farming.
Sultanic Agricultural Society, Bulletins, (Technical section.)
Union of S. Africa, Journal Dept. of Agriculture.
Wallace Farmer.
Washington Farmer.
West Indian Bulletin.
Washtenaw Post.
Wilson Bulletin.

The publications of the United States Department of Agriculture and of the various agricultural experiment stations are received and filed in the library. We receive the catalogues of the leading educational institutions in exchange for our own catalogue. We also receive from the United States Superintendent of Documents such publications as are sent to depository libraries.

We gratefully acknowledge our indebtedness to the librarians of the University of Michigan, The John Crerar Library, The University of Chicago, The Johns Hopkins University, the United States Department of Agriculture, and the United States Surgeon General's Office for their courtesy in loaning to us certain publications needed by our research workers.

The number of books loaned for home use during the year was 9,876, an average of 817 per month.

The work in the reference department has increased materially during the year. We now have package libraries covering 362 subjects, ready for circulation. Five hundred circular letters have been sent out, and 95 package libraries have been loaned. Bibliographies on the "Preserving of Fruit," "Millinery," "The History of Table Service," and "The History of the Plow" have been prepared in response to requests.

We feel that the package libraries are quite as much appreciated by our students and faculty, as by the people away from the College, since they are in constant demand, and we also feel that this new venture is quite worth while.

In August of 1921 the Dean of Home Economics transferred to the general library all books belonging to the department. These books have become a part of the library, and there is no longer a library in the Home Economics department.

For the members of the library staff I have only words of commendation, and I desire to thank them all for their loyalty and splendid co-operation.

The Experiment Station library grows but slowly. Of bound volumes

146 have been added, of which 11 were purchased, 7 were gifts, and 128 came by binding. Of the books purchased, all but three went into department libraries.

The College library numbers 40,309 volumes, the library of the Experiment Station numbers 5,079 volumes. Total in both libraries, 45,388 volumes. This number includes department books so far as they have been catalogued.

Respectfully submitted,
LINDA E. LANDON,
Librarian.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE HEALTH SERVICE.

To the Honorable State Board of Agriculture and the Health Service Committee:

We submit the following report of Health Service activities at the Michigan Agricultural College from June 20, 1921, to June 23, 1922, inclusive.

STATISTICAL.

	Dispensary	Hospital	Total
Dispensary Calls	6,059	772	6,831
New Patients	1,402		1,402
New Diagnoses	4,039		4,039
Reported Room Calls			73
Hospital Bed Patients			170
Deaths			1

N. B. Figures are based on average attendance per term for the year.

DISPENSARY.

Number of treatments given	6,059
Daily average	25.6
Percentage of calls based on registration	427.7
Percentage of patients based on registration	99.0

HOSPITAL.

Total number of patients	170
Average number of days per patient	5.4
Percentage of calls based on registration	54.5
Percentage of patients based on registration	12.0

LABORATORY.

Urines	610
Sputum	4
Blood count	96
Smear, tonsil	7
Smear, throat	8
Culture, blood	2
Culture, purulent exudate	1
Culture, throat	18

CONDITIONS TREATED

Abscess	17
Achromatopsia	1
Acne	80
Adenitis	3
Adenoid mouth	2
Adhesions	1
Albuminuria	11
Alopecia	1
Amaurosis	2
Amnesia	1
Anaphylaxis	4
Angina pectoris	1
Aortic disease	3
Aortic regurgitation	2
Appendicitis, acute	26
Appendicitis, chronic	5
Arythmia	4
Arthritis, acute	10
Arthritis neisser	1
Asthenopia	48
Asthma	8
Atrophy	4
Atrophy, testicle	1
Attached lobes	12
Blindness	1
Bow legs	1
Bronchitis, acute	52
Bronchitis, chronic	4
Broncho-pneumonia	5
Bunion	1
Burn	22
Carbuncle	3
Cardiac decompensation	3
Cauliflower ear	2
Chalazion	1
Chickenpox	5
Clavis	8
Colitis	1
Conjunctivitis, acute	22
Constipation	10
Cyst	4
Deafness	6
Dental caries	36
Dermatitis, medicamentosis	1
Dermatitis, seborrhoic	1
Dermatitis, venenata	14
Deviated septum	99
Diabetes	1
Diarrhea	2
Diphthera	1
Dislocation	4
Dislocation, congenital hip	1
Dyshidrosis	5
Dysmenorrhea	71
Eczema	6
Enteritis, toxic	55
Epilepsy	2
Epistaxis	4
Erythema, exudative	5
Erythema, nodosum	1
Erythema, toxic	1
Extra systole	2

Fissure	1
Foreign body	18
Fracture	13
Frost bite	1
Furunculosis	90
Gingivitis	1
Goitre	53
Goitre, exophthalmic	2
Gonorrhea	1
Hammer toe	1
Heart block	1
Hemorrhage, gastric	1
Hemorrhoids	11
Hernia	23
Herpes, simplex	21
Herpes, zoster	3
Hiccough	1
Hordeolum	14
Hydrocele	5
Hygienic advice	7
Hyperacifity	4
Hyperchlorhydria	17
Hyperhidrosis	10
Hypertension	3
Hypertrophy, cardiac	1
Hysteria	1
Iliosacral arthritis	5
Immunization, anti-diphtheria	2
Immunization, anti-furunculosis	4
Immunization, anti-typhoid	53
Impacted cerumen	33
Impetigo contagiosa	31
Infection, local	147
Influenza	5
Ingrowing toe nail	1
Insect bite	5
Insomnia	1
Jaundice, acute catarrhal	13
Joint mouse	1
Keloid	2
LaGrippe	17
Laryngitis, acute	15
Lost, fingers	1
Lymphadenitis	16
Lymphangitis	1
Mastoiditis	1
Measles	1
Mitral disease	16
Molluscum fibrosum	2
Mucocele	1
Mumps	3
Myalgia	35
Myalgia, traumatic	4
Myocarditis	2
Myringitis	9
Naso-pharyngitis, acute	97
Nephritis, acute	2
Nephritis, chronic	1

Neuritis	1
Neuritis, multiple	1
Night blindness	1
No disease	32
Observation	55
Onychomycosis	1
Oophoritis	1
Orchitis, acute	2
Osteomyelitis	1
Otitis media, acute	10
Otitis media, chronic	5
Paralysis	1
Paronychia	2
Perforated septum	2
Pericardial effusion	1
Pericarditis	1
Pes planus	4
Pharyngitis, acute	243
Phimosis	6
Physical examination	614
Pityriasis rosea	3
Plantar wart	8
Pleurisy	14
Pneumonia	4
Polyarthritis	1
Pruritis ani	1
Psoriasis	1
Pyelitis	1
Pyorrhea	1
Quinsy	5
Refer, private physician	40
Refractive error	129
Residual ant. polio paralysis	4
Retroversion	3
Rhinitis, acute	216
Rubella	1
Scabies	28
Scarlet fever	1
Sciatica	1
Scoliosis	8
Scotoma, scintillating	1
Seborrhea	1
Shoe pressure	2
Sinusitis, acute	34
Spermatocele	1
Spondylitis	1
Sprain	54
Strabismus	1
Sunburn	1
Tachycardia	12
Tenosynovitis	6
Thrombosis	2
Trhyoiditis, suppurative	1
Tinea, axillaris	1
Tinea, circinata	1
Tinea, cruris	22
Tinea, versicolor	4
Tonsillitis, acute	76
Tonsillitis, chronic	165
Tracheitis, acute	176
Trauma	212
Trichophytosis, profunda	1
Tuberculosis, healed	6
Tuberculosis, suspect	1
Ulcer	8
Ulcer, gastric	1
Undescended testicles	2
Unerrupted molar	13
Urtehritis	1
Vaccination	163
Vaccination inspection	129
Vaccination refused	20
Varicocele	11
Verrucca	15
Vincents angina	5
Vitiligo	2
Whooping cough	1
Wound, gunshot	1

Respectfully submitted,

CLYDE REYNOLDS, M. D.,
Director of Health Service.

East Lansing, Michigan, June 30, 1922.

REPORT OF DEAN OF APPLIED SCIENCE.

President Friday:

In presenting the first annual report of this newly established division I feel it proper to devote some attention to the history of the development of scientific work both in instruction and research at M. A. C. in order that it may be understood how the establishment of this new division may be seen as a natural developmental outgrowth of the policies inherent in this College.

The idea which permeated the addresses given at the opening exercises held here in May, 1857, was that science must be applied to the solution of agricultural problems, that the newly founded college must strive to discover new facts of practical value to farmers, in addition to giving liberal courses of study to young men in which the known principles of physical and natural science were to be taught with special emphasis on their relation to the practical affairs of life.

It was to be anticipated that as the College increased in number of students the Departments of Botany and Chemistry, which were the two scientific departments first established, would not only be greatly enlarged as attendance increased but that other related subjects of scientific inquiry would be organized into separate departments.

In the founding of this College the State was not niggardly in providing adequate scientific equipment. The north half of the first floor of old College Hall was a well-furnished chemical and physical laboratory provided with up-to-date (1857) apparatus, this equipment being comparable in extent with that possessed by any college in the middle west.

The large (48 inch) plate glass wheel of the frictional electric machine mounted in a solid mahogany frame was enclosed in a large blue-curtained glazed case and occupied one end of the rostrum of the College chapel. It gave the student, while attending daily prayers, an inkling of how deeply he would be enabled to penetrate the mysteries of nature in the newly established Agricultural college. As a small boy I regarded this cabinet containing the wonderful electric machine with much of the awe with which the Jews regarded the Ark of the Covenant, and I have little doubt it was equally impressive to the incoming student.

"Learn by doing" was the motto of M. A. C. from the outset. Thus the requirement from each student of three hours manual labor on the farm or garden, daily, in the afternoon, while in the morning hours his time was devoted to class recitation and laboratory work,—the latter being emphasized to a hitherto unheard-of extent. (Example: a three-hour period devoted to analytical chemistry daily!)

The desire for a separate building for laboratory purposes was first attained on the campus by the construction of the new chemical laboratory (1871) at an expense of $12,000. This was furnished with hoods for ventilation patterned after those of the laboratory at Bonn (Germany) University. (This first laboratory building is still in use.) A few years later a botanical laboratory of wood construction followed. (Burned 1888). These two laboratories may be considered as the determining factors in the adoption of the policy of separate laboratories for the college scientific departments. The results of the scientific researches carried on in botany, chemistry and entomology between 1870-90 at M. A. C. had much to do in establishing its reputation not only with the farmers of Michigan but in the nation also. Students were drawn to M. A. C. by the reputation which the College had earned for giving thorough training in the elementary sciences.

Continued growth of the College brought additional laboratory buildings—greater demand for time for experiment in the laboratory on the part of the student. This demand for time and more laboratory work resulted finally in the abandonment of the required labor system (1895).

Laboratory research in "Land Grant" colleges was greatly stimulated by the various Congressional grants known as the Hatch (1887), second Morrill (1890), Adams (1906), and Nelson (1907) acts. The immediate result of the Hatch Act was the establishment of agricultural experiment stations throughout the nation. Naturally many of our graduates became experiment station workers serving as bacteriologists, botanists, chemists and entomologists in addition to a number who engaged as technical agricultural experimenters in live-stock, dairying, crops, horticulture, etc. Familiarity with the problems of an administrative character gained by contact with details of experiment station work resulted in many of our graduate workers being promoted to the position of Station Director.

The decision to establish a separate course of study of a purely scientific character was arrived at, not only to meet a desire expressed by many students for a curriculum of study which did not necessarily involve technical courses in either agriculture, engineering or home economics, but gave the opportunity for specialization in some particular science; but more than this to provide a course which should attract to it students who had the inherent ability to become research workers, not only for the benefit of our agricultural experiment stations, but also for the benefit of our many industrial and manufacturing establishments.

I feel that what has been accomplished by this institution in the development of scientific workers in the past, can be largely augmented in the years to come by the opportunities offered, and the more specialized training given, by the courses of the Applied Science Division.

Beyond the first year the curriculum is entirely elective, although the sophomore student is restricted in his elections in order that he may be prevented from too great specialization. The work required before graduation from all Applied Science students is: chemistry, one year, English, one year, mathematics two-thirds of a year, physics two-thirds of a year, drawing, economics each one-third of a year, history one-seventh of a year.

Beginning with the junior year, a major and a minor subject is chosen. For 1922-23 the following are offered as majors: bacteriology, botany, chemistry, economics, entomology, history and political science, mathematics, physics and zoology. For minors: English and English literature, modern languages, geology, physiology. A major subject requires twenty or thirty credits work per year; a minor, ten or fifteen credits. Additional to this major and minor work the student is guided in his selection of other subjects by the advice of the dean and the head of the department in which he majors.

The enrollment in the course for the current year totaled one hundred and twenty-two students; men, one hundred and nine, women, thirteen; classified as freshmen, ninety-eight, sophomores, twenty-four.

The Faculty Committee charged with the responsibility of organizing the curriculum for the division consisted of Dr. E. A. Bessey of the Botany Department (Chairman), together with Professor E. H. Ryder (History) and Professor L. C. Plant (Mathematics). The plan as originally submitted by them was adopted by the faculty April 8, 1921, and has not been changed so far with the single exception that the number of major subjects has been increased from four to nine.

I believe we shall see a continued growth in numbers and interest in this new venture. The effect on our undergraduates already is to encourage them to pursue graduate courses—to come up higher.

Acknowledging heartily your cordial co-operation in this promising field of work, I respectfully submit this first report.

FRANK S. KEDZIE,
Dean of Applied Science.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF BACTERIOLOGY.

President David Friday,
Michigan Agricultural College.
Dear Sir:

The only changes in our teaching program during the past year are those resulting from outside influences. Changes in the curricula of the Home Economics course have brought to me an extra class in Bacteriology 1, spring term, and juniors in Food Major and seniors in Vocational Home Economics who will be required hereafter to take Sanitary Science 14 instead of H. E. 33. The Science course has already made it necessary for Mr. Mallmann to outline and give Bacteriology 4a, Antiseptics and Disinfectants, and has caused each member of the department to proceed as rapidly as possible with the task of developing courses in Applied Bacteriology covering nearly every phase of the subject. I cannot speak too highly of the fine spirit in which the men have undertaken their added duties. Their efforts give assurance that the work offered by us to students in the Science Course will measure up to the standards of the College. These same men are guiding a few—too few—men and women in research to the mutual advantage of the instructor and student, thus assuring the building up of graduate work of a high and distinctive type.

The following table gives an idea of the distribution of classroom work for the four terms:

Summer Term, 1921.

Courses.	Number of Students.	Instructor.
Bacteriology 1	24	Ward Giltner
Bacteriology 1a	2	Ward Giltner
Bacteriology 1b	3	Ward Giltner
Bacteriology 1c	6	Ward Giltner
Bacteriology 103	1	Ward Giltner
Bacteriology 105	1	Ward Giltner
Bacteriology 3	3	F. W. Fabian
Bacteriology 4	1	F. W. Fabian
Bacteriology 13	9	Ward Giltner
Bacteriology 14	8	Ward Giltner
Bacteriology 2	11	F. W. Fabian
Bacteriology 23	2	F. W. Fabian
Bacteriology 105	1	R. L. Tweed

Fall Term, 1921.

Courses.	Number of Students.	Instructor.
Bacteriology 3	8	F. W. Fabian
Bacteriology 24	22	F. W. Fabian
Soil Bacteriology	1	R. M. Snyder
Hygiene 25	189	Ward Giltner

Bacteriology 13	21	Ward Giltner
Bacteriology 1	63	Ward Giltner
Bacteriology 105	1	R. L. Tweed
Bacteriology 1a	119	Ward Giltner
Bacteriology 2	32	W. L. Mallmann
Bacteriology 4	15	W. L. Mallmann

Winter Term, 1921-1922.

Bacteriology 1b	122	Ward Giltner
Bacteriology 2	14	F. W. Fabian
Bacteriology 3	22	F. W. Fabian
Bacteriology 2	12	W. L. Mallmann
Bacteriology 4	11	W. L. Mallmann
Bacteriology 100	1	W. L. Mallmann
Bacteriology 105	1	R. L. Tweed
Agricultural Bacteriology	28	R. M. Snyder
Butter Making	30	G. L. Ruehle
Ice Cream Making	20	G. L. Ruehle
Dairy Production	30	G. L. Ruehle

Spring Term, 1922.

Bacteriology 19	21	H. J. Stafseth
Bacteriology 1c	108	Ward Giltner
Bacteriology 1	48	Ward Giltner
Bacteriology 14	13	Ward Giltner
H. E. 33	25	Ward Giltner
Bacteriology 15	3	R. L. Tweed
Bacteriology 2	10	F. W. Fabian
Bacteriology 3	9	F. W. Fabian
Bacteriology 23	42	W. L. Mallmann
Bacteriology 103	1	L. H. Cooledge

If I may be permitted to express the departmental view on a matter of institutional policy, I do not hesitate to say that the best interests of the College and the Experiment Station, servants of the Commonwealth, will be advanced by liberalizing our program, by reducing the number of hours required of students in the classroom, by employing relatively more assistants and fewer directors in research and teaching, by encouraging (even to the extent of compulsion) study, the investigative spirit and high ideals of scholarship on the part of all employees, and above all by promoting post-graduate work. I need not insult your intelligence by listing the merits of these suggestions; they are obvious. A change of policy with these matters in mind need not and, I assure you would not, mean that the College would depart from its traditional policy of service to the people of the State—to humanity in fact—nor yet from its unique position of rendering particular service in the practical and tangible fields of agriculture and the mechanic arts (with all that these broad terms imply). On the contrary such a program, courageously adopted, and persistently followed, would, with a competent, sympathetic, and loyal personnel, mean undreamed of things for agriculture, for engineering and for human welfare in general.

May I assure you in behalf of the Department of Bacteriology and

Hygiene of the great esteem in which we held your predecessor, Dr. R. S. Shaw, of his fine spirit of helpfulness in all our efforts and lastly of the pledge of our hearty approval of your plans for the College insofar as they have been announced, and of our unqualified support of your efforts to bring those plans to fruition.

Respectfully,
WARD GILTNER,
Professor of Bacteriology and Hygiene.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF BOTANY.

President David Friday,
Michigan Agricultural College.

Dear President Friday:

In accordance with custom, I make the following report for the Botanical Department for the fiscal year ending June 30th, 1922.

The staff of the department has remained the same as in the preceding year, except for the following points:

Mr. Lionel E. Tisdale, Half-time Graduate Assistant, having completed his work for th M. S. degree, severed his connection with the College in the summer of 1921 and took a position at Clemson College, South Carolina.

Mr. Henry T. Darlington, Associate Professor of Botany, was granted a leave of absence during the winter term for the purpose of further study at the University of Chicago.

Dr. R. P. Hibbard, Research Associate in Plant Physiology, was invited by Johns Hopkins University to come to Baltimore and co-operate with the Department of Plant Physiology at that institution in the study of the salt requirements of the wheat plant. The State Board of Agriculture agreed to enter into this co-operation between the two institutions and authorized Dr. Hibbard to go to Baltimore for this purpose for the period September 1st to June 30th. During Mr. Hibbard's absence the teaching work in Plant Physiology was carried on by H. C. Young.

At the request of the Plant Disease Survey of the U. S. Department of Agriculture, Dr. G. H. Coons, Associate Professor of Botany, was permitted to go to Washington for the month of January to assist in collating the reports on plant disease occurence throughout the country for the preceding year, and at the same time to look up the literature of certain subjects which have been studied here for several years.

The past year has seen an increase in the number of students taking botany, due in part to the increase in the total number of students in college, and in part to the fact that certain new courses were offered. The greatest increase came from the requirement that freshmen in the technical series of the Household Economics course take one term of botany in the fall term. The course in Elementary Genetics also drew a good sized class.

The necessity of taking over 100 women students for one term only, all in the same term, makes the fall term an exceedingly crowded one, both as regards demand on the instructional force and on laboratory space in which to conduct the classes. If the expected increase in the number of students materializes next fall it will probably be necessary to conduct some classes in the evening.

The attempt has been made to maintain the Botanical Garden at its former high standard of scientific value and public interest. Numerous perennial plants were purchased to replace plants that had died, or those of less importance, as well as to add species not represented. The aim has been constantly to add, as far as possible, species that are native to the State, as well as shrubs not native here but which might be expected to be of value for ornamental or other purposes. Still other plants were added merely for their scientific interest.

Many specimens of Michigan plants have been added to the Herbarium. These are mainly the spoil of collecting trips made in co-operation with the Geological and Biological Survey in previous years, as well as plants collected on short trips and those donated by interested amateurs. An insufficiency of funds has prevented the acquirement of many valuable sets of specimens which would have added very greatly to the value of the Herbarium, for a herbarium, like a library, is of increasingly great value as it represents collections from more sources.

The work on the Flora of Michigan has progressed slowly because of lack of suitable help, it being impossible for Professor Darlington to devote much time to his work and also supervise the Herbarium and Botanical Garden in addition to his teaching. However, a number of the larger families have been worked over and are practically ready for incorporation in the Flora. Professor Darlington has already published a paper in the Michigan Academy of Science Report for 1919 on the Orchid Family and has the Grasses and Sedges practically completed. Miss Bertha E. Thompson, Assistant Professor of Botany, has worked up the Violet Family. Professor Darlington and I have been working over the Flora of Gogebic County, a region of great scientific interest because of its location with reference to western and northern immigrant plants.

In addition to the teaching and the other work mentioned, a large amount of time is devoted, particularly in the spring and summer months, to the answering of letters regarding the identification of plants, the control or eradication of weeds, and a thousand and one other questions which a botanist can be called upon to answer.

In 1913 some of the advanced students in botany organized an honorary botanical society to which membership is open only to those who are able to pass a stiff examination in botany. Those who are invited to take this examination are picked from those students whose botanical work has been uniformly good. This honorary botanical society, the Botanical Seminar, in addition to its regular meetings has made it a practice to bring in from outside the College some well known botanist to give a public address. For the year just closed, the speaker was Dr. Bradley M. Davis, one of the Professors of Botany at the University of Michigan. The subject of his very instructive lecture was "Problems of the Origin of Variations."

The number of graduate students in botany has been small the past year, there being only two majoring in the subject. One of these, W. D. Mills, Halftime Graduate Assistant, has completed his work for the M. S. degree, while the other, Panos D. Caldis, will complete the third term at the close of this summer, at which time he will go to the University of California where he has been awarded a fellowship. It is gratifying to note that those who major in botany have been able to find places upon the completion of their work here, which would indicate that the work was recognized as of good grade.

In conjunction with Professor L. H. Harvey of the Western State Normal School, I have been asked to advise with and plan for the botanical work of the Land Economic Survey which is conducting a preliminary survey this summer in Charlevoix County and will probably extend its field to several other counties next year.

Respectfully submitted,
E. A. BESSEY,
Professor of Botany.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF CHEMISTRY.

President David Friday,
Michigan Agricultural College.
Dear Sir:

I have the honor to submit the following report on the work of the Department of Chemistry for the year ending June 30, 1922. The teaching staff for the year was as follows:

A. J. Clark, Professor.
R. C. Huston, Associate Professor.
H. S. Reed, Associate Professor.
B. E. Hartsuch, Associate Professor.
D. T. Ewing, Assistant Professor.
H. L. Publow, Assistant Professor.
P. S. Brundage, Assistant Professor.
C. D. Ball, Assistant Professor.
E. F. Eldridge, Instructor.
H. D. Lightbody, Instructor.
W. C. Lewis, Instructor.
R. L. Baxter, Instructor.
H. M. Krebs, Instructor.
M. L. Grettenberger, Assistant.

The unification of the work in chemistry in the freshmen year of all divisions was put into effect this year. This was of great value in that we were enabled to handle over one hundred additional students per term, with one less instructor than formerly. The fact that only one change was necessary in the personnel of the department insured a smoothly working, efficient organization. I cannot speak too highly of the fine spirit of co-operation existing throughout the department.

I wish to speak particularly of the work of Professor Ewing in developing our work in Electro-chemistry. I believe this work will eventually attract attention from outside as well as furnish valuable data to Michigan industry.

Professors Huston and Hartsuch also have valuable work in progress along the lines of animal nutrition and textiles respectively.

I am co-operating with Professor Spragg in analysis of the wheats grown in the College experimental plats.

The handicap mentioned in my last report; namely, the scattering of the department among four buildings and congested conditions, still holds true. During the Christmas holidays it was necessary to crowd more tables and locker space into Laboratories A, C and F. I believe next year we can take care of approximately fifty to sixty more freshmen students than we have had this year, but that will be the limit.

With some additional floor space to be obtained, by enclosing the concrete court on the north of the new part of the building, we are planning on taking care of the work in Electro and Biological Chemistry to better advantage, but it must be realized that if the department is to progress in any large sense a new building in the immediate future is essential.

Forty-four courses have been offered during the year. The number of students enrolled in the department during the year was as follows:

Summer Term, 1921	83
Fall Term, 1921	735
Winter Term, 1922	956
Spring Term, 1922	705
Total	2479

Respectfully submitted,
ARTHUR J. CLARK,
Professor of Chemistry.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF ECONOMICS.

President David Friday,
Michigan Agricultural College.

Dear Sir:

The following is the report of the Department of Economics for the year 1921-22.

The total enrollments for the year were 965, distributed as follows:

By terms: Fall, 390; winter, 260; spring, 260; summer, 55.
By classes: Senior and junior, 600; sophomore, 218; freshman, 248.
By subjects: Economics, 804; Sociology, 161.

The total number of hours taught during the year by members of the department was 1354, divided as follows:

By terms: Fall, 444; winter, 348; spring, 346; summer, 216.
By subjects: Economics, 1114; Sociology, 240.
By teachers: Mr. Hedrick, students, 372; hours, 492.
Mr. Dunford, students, 249; hours, 504.
Mr. Horner, students, 299; hours, 348.

The department during the past year has made some creditable gains. Some eight or ten courses have been added, mostly in the Applied Science Division,—and a new teacher. Professor Horner came to us from Columbia University and has had charge of the classes in Applied Agricultural Economics. We have had gains, too, in the number of students who have elected subjects in the department, as a comparison of this report with that of last year will show. A recent interest is shown, also, by the fact that some five students have now enrolled for graduate study, using economics either as a major or minor.

Very respectfully,
WILBUR O. HEDRICK,
Professor of Economics.

East Lansing, Michigan, June 30, 1922.

DEPARTMENT OF ENGLISH AND MODERN LANGUAGES.

President David Friday,
Michigan Agricultural College,
Dear President Friday:

I submit for your consideration the following report on the work of the Department of English and Modern Languages for the year ending June 30, 1922.

The table below gives the number of student enrollments in the department for the year. In previous reports I have differentiated between modern languages and English but have not differentiated between public speaking and the courses in literature and composition. This year, for greater clearness, I list the public speaking separately.

	English: Literature and Composition	Public Speaking.	French.	Spanish.	German.	Total.
Summer Term, 1921	53	20	14	....	....	87
Fall Term, 1921	742	143	104	139	10	1,138
Winter Term, 1922	726	274	86	116	10	1,212
Spring Term, 1922	856	173	75	87	10	1,201
Total	2,377	610	279	342	30	3,638

The number of enrollments for the year exceeds the number for last year by 1033, an increase of more than 39 per cent. We lack but three of having as many enrollments in literature and composition as we had last year in literature, composition and public speaking, and at the same time we have in public speaking a registration of 610. Our increase in French is 128, and in Spanish 268. We have handled this large increase in English, public speaking, Spanish and French with the same number of teachers as last year, and have in addition given daily instruction throughout the year to one class in German, a subject not given last year. I believe that we have given instruction to many more students than were handled by any other department; we have also maintained several extra-curriculum activities, such as intercollegiate debates, literary contests and our dramatic representations.

The teaching staff for the year was as follows:

W. W. Johnston, Professor of English and Modern Languages.
Egbert S. King, Associate Professor of Public Speaking.
Ray B. Weaver, Assistant Professor of English.
Norma G. Roseboom, Assistant Professor of English.
Leo C. Hughes, Assistant Professor of French.
Omer L. Lebel, Assistant Professor of French.
Albert H. Nelson, Assistant Professor of English.

Reuben Thornton Taylor, Assistant Professor of English (fall and winter).
Louis B. Mayne, Instructor in English.
Willard H. Bonner, Instructor in English.
Lewis P. Waldo, Instructor in English.
J. Walker Milne, Instructor in Public Speaking.

In addition to those named above I employed Mr. Lu Willson during the winter and spring terms, paying him from department funds. In the winter term the extra help was made necessary by an unfortunate unbalancing of our public speaking schedule due to a change made two years ago in the program of the Engineering Division. During the spring term I retained Mr. Willson to fill the gap made in my staff by the resignation of Assistant Professor Taylor.

Two of my staff have resigned. Near the close of the winter term ill health compelled Professor Taylor to entrust his classes to other members of the department, and by the end of the term it had become clear that he must abandon the teaching profession for at least a year. Accordingly he submitted his resignation, which was accepted with great regret. Mr. Taylor is a man of ability, of character and of very attractive personality. His loss will be keenly felt.

In June, Mr. Bonner resigned in order to accept a position in the College of Liberal Arts of the University of Buffalo. Mr. Bonner, though young, impressed students and all who knew him, as an extremely effective teacher. He combines a clear knowledge of his subject with exceptional ability in the classroom. I am very sorry to give him up, but he feels that in a college of liberal arts he will find an environment in which he will grow more rapidly than here.

I have also lost Mr. Waldo for at least a year.

Mr. Waldo has been highly honored by being granted by the Republic of France a scholarship which will provide for a year's study in French universities. It is my hope that he may return to us at the expiration of the leave of absence granted him by the Board of Agriculture.

I also wish to mention here that Assistant Professor Paul E. Brees, not listed above, resigned in August 1921, his resignation being made too late to be recorded in my last annual report. Mr. Brees resigned in order to accept a position in Kalamazoo College. Mr. J. W. Milne was secured to take up the work which he laid down.

As you consider the division of subjects in the table given above and as you scan the titles of the departmental staff, it will readily occur to you that in my department you have under one administrative head at least three departments, namely, a department of English, a department of public speaking and a department of modern languages. This statement is conservative, for in many institutions the subjects which we group together in one department are divided among as many as five departments, the three-part division being further broken up by the separation of literature from composition and of romance languages from other languages. Since we now have in the department a distinct separation of courses and of teachers into three distinct groups I see no reason why a division of my department into three departments should not be made in the near future.

The major extra-curriculum activities conducted by the department are the Lawson Essay Contest, the Eunomian-Holcad Literary Contest, our intercollegiate debates and our dramatic representations. The Lawson Contest was won by C. Russell Clausen, a junior agricultural student. Mr. Clausen's essay was entitled "The Farm, Nation Builder". The Eunomian-Holcad Contest was won by Mr. Fred W. Henshaw, a special agricultural student. Mr. Henshaw received first prize, $25, for a poem entitled "Cities". Other prizes were won by Marian Ward, H. E. Segelin, Cleon Green and Victor Kinson.

In my report last year I said something in regard to the publication, in periodicals and books, of literary work brought out by the Eunomian-Holcad contest. I may add here that there has been at least one year in which Michigan Agricultural College has been honored by having more poems accepted for publication in "Poets of the Future", a volume published by the Stratford Company, than the University or any other institution in the State. A contest which has in six years brought out literary talent as has this competition should have its continuance assured. Yet there is no permanent fund whatever behind the Eunomian-Holcad contest. Surely the College has many a good friend who loves works of the imagination and wishes to encourage imaginative writing at M. A. C. Cannot some such person be found who will give $1,000 as a permanent fund to keep this contest going? Sixty dollars a year, the interest from $1000 at 6 per cent, would more than double the amount of prize money available this year. Then too, if the present support, amounting to $50 a year, should be withdrawn, this fund would more than make up the loss. Since it is your desire and purpose to foster all kinds of creative work at M. A. C., I take this means of calling your attention to one way in which creative work may be further encouraged.

The men taking part in intercollegiate debate this year were:

Leroy Keely, Howard Menhinick, Harry G. Smith, Victor Whittemore, Earle Chapman, Burwell Cummings.

Our series of debates was much more extensive than any previously carried on at the College. A great step in advance was made when we organized eight years ago our tri-state debate with Iowa State College and Purdue University. The organization of this contest stimulated our students to increased interest in forensic activities and has resulted in sending out a number of graduates well prepared to speak effectively on the public platform. This year's further augmentation of debating has aroused much interest in the student body. In addition to carrying out our regular tri-state debate we sent Menhinick, Keely and Smith on a debating trip which took them through Illinois, Iowa, Colorado, Utah, Montana, North and South Dakota and Minnesota. On this trip our boys debated Western State Normal College, Monmouth College, Iowa State College, Colorado Agricultural College, Montana State College, Montana Wesleyan College, North Dakota Agricultural College, South Dakota State College and St. Olaf College. Some of these debates were held with the one-judge system, some with three judges, and three with no judges. It would be hard to exaggerate the solid benefit which our boys derived from this trip. To meet, night after night, often after tiresome and tedious travel, strong, spirited and well-prepared opponents and to discuss with each other and with their coach new phases of the debate question and of the tactics of presentation brought out in hotly contested debates—these are matters of great moment in the making of a debater and in the moulding of character as well. Of the debates in which a decision was rendered our team won twice as many debates as it lost. It is with great pleasure that I have read the comments made on the team in the papers published by the students of the institutions in which our men debated. Our boys acquitted themselves as debaters and as men. They won gallantly and lost gallantly. They were freely accorded the superiority in one institution in which no formal decision was rendered. They left on the minds of those who heard them a most favorable impression of our forensic activities, our debaters, and the institution which sent them forth.

In connection with our debates I wish to refer to their financial support. Some ten years ago when the blanket tax was first adopted the student body and the faculty recommended that a definite percentage of this tax to be devoted to our forensic contests. The Board of Agriculture, however, decided that instead of dividing the blanket tax the Board itself would get behind these contests and support them adequately, even generously, through an annual grant of funds to the English Department This policy has been adhered to consistently. With financial support assured, our contests have been a credit to the institution. More students try out for our teams, our debates improve in quality from year to year, and more and more it has become clear that our debaters go out from M. A. C. as graduates of whom we are proud. They show after graduation that they possess genuine ability to make themselves felt for good in the life of the State. I ask that you satisfy yourself of these facts and that the financial backing promised us under a preceding administration be forthcoming year after year. Mr. Milne has devoted himself to our contest work with great ability, and the carrying on of these debates takes much of the time of others besides the coach. We give this time gladly and ask in turn that our efforts receive full administrative support.

Two plays were given this year under the direction of Professor King. In the fall term a modern comedy was given in the auditorium of the People's Church. The house was crowded, and the play was well received. In the spring term the annual commencement play in the Forest of Arden was given, the play chosen this time being "The Merry Wives of Windsor". All members of the cast conducted themselves creditably and a large number of people saw the performance, every seat being taken.

I wish to express my appreciation of the very fine service rendered by the members of my staff and of the splendid spirit with which the men carried a schedule which was at times excessively heavy. I wish to thank you for the interest which you have shown in us and to express the hope that the Department of English may develop rapidly under your administration. I firmly believe that it would be wise to establish without delay a major in English in the Division of Applied Science. Already we have the teaching staff and the courses of instruction for major work. When the University is so crowded with students as to be clamoring for relief and when many excellent young people here are eager to take more English than is permitted in any one division, it would, I am convinced, be to the interest of all concerned to establish a major in English. With such a major established I should have much less difficulty in obtaining and holding a teaching staff of high grade. I frequently lose men who wish to go to other institutions where major work is given by the Department of English. Last year, for instance, I lost Mr. Greene, a fine instructor, who accepted a position in Cornell University, not because the salary was better, for it was not, but because while teaching in Cornell he himself could take some advanced work. Mr. Bonner leaves me this year for a similar reason. These are but two of several instances which I could name. I see no reason why we should work longer under this handicap. Nothing whatever seems to be gained by it; much is lost. Why should we not line up with Washington State College, Iowa State College and Cornell University? These agricultural colleges, each the best in its part of the United States, place English in a position of influence which is denied to it here. I venture to urge therefore that when the catalog for 1922-23 is published the subject of English be listed among the majors offered in our new Division—listed, that is, with physics, history and the other scientific and non-scientific subjects now officially recognized as major subjects in this institution.

Very respectfully submitted,
WILLIAM W. JOHNSTON,
Professor of English.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF ENTOMOLOGY.

President David Friday,
Michigan Agricultural College.
Dear Sir:

Following is a brief report of the work of the Department of Entomology for the year ending June 30, 1922.

During the year, the following changes in personnel of the department have taken place: Mr. J. L. L. Frank, half-time graduate assistant who is taking his major in parasitology under the direction of Dr. Chandler, finished his term on August 31, and was succeeded by Mr. S. T. Flynn on October 1st.

On April 1st, 1922, Mr. R. M. Hain resigned from the position of Extension Specialist in Entomology to be succeeded by Mr. John H. Harman who commenced work on May 10, 1922. Mr. Harman is a graduate of Michigan Agricultural College and has been for several years past employed by the U. S. Department of Agriculture in work against the European corn-borer in New York and in Massachusetts. At the time of coming here Mr. Harman was in charge of the research sub-station at Poughkeepsie.

During the Summer of 1921, Course II, a course dealing with the control of fruit pests, was given, also a two weeks' course in Nature Study and lectures to Agricultural High School teachers.

During the fall term the following courses were given:

Entomology III	Field Crop Insects.
Entomology VIII	Introduction to Parasitology.

Entomology IXc, Xb and XI, three separate courses in Apiculture.
A four weeks short course in poultry and fruit insects.
Entomology Xc, a regular course (option in agiculture).

A special course of five credits to a large class of Federal students.
A short course in apiculture running eight weeks was given to Horticultural short course students.
A short course in the control of fruit pests to Horticultural students.
A regular short course to second year students in General Agriculture for eight weeks' and for second year men of the sixteen weeks' course.
A special course for students in farm business, meeting five times a week for four weeks.

During the spring term the following courses were given:

Entomology III Fruit Insects.
Entomology I Introduction to Study of Insects.
Entomology Va and Vb Systematic study of scale-insects.
Entomology IXb Apiculture (elective for seniors).
Entomology Xa Apiculture (option for beekeepers).
Entomology Xd Apiculture (option for beekeepers).
Two courses to Federal students, F3 and F6.
Entomology 101, graduate work in parasitology, was given during the entire year.

The constantly increasing numbers of Federal students taking apiculture has necessitated the establishment of several out apiaries. Something over ninety Federal students have taken work in apiculture during the year. Our quarters are rather inadequate for handling so many extra men and some ingenuity has been necessary in order to provide for some of the instruction.

Respectfully submitted,
R. H. PETTIT,
Professor of Entomology.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF MATHEMATICS.

President David Friday,
Michigan Agricultural College.

Dear Sir:

I have the honor to submit for your consideration the following report on the work of the Department of Mathematics for the year ending June 30, 1922.

During the year the teaching staff of the department was as follows:
L. C. Plant, Professor.
L. C. Emmons, G. G. Speeker, S. E. Crowe, Associate Professors.
F. E. Wood, V. G. Grove, Assistant Professors.
R. C. Huffer, J. E. Robertson, S. J. Daley, Instructors.

The success of a department must necessarily come through its individual members. No small amount of the efficiency of the Department of Mathematics is due to the graduate work done by the members of the staff. During the past year Chas. T. Bumer, who has been on leave of absence, has done advanced work at Harvard University and Vernon G.

Grove and Stanley E. Crowe spent the summer quarter in the University of Chicago.

The department will suffer the loss of Dr. Frank E. Wood, a most capable research man, who has accepted an assistant professorship at Northwestern University.

Professor Emmons and Dr. Wood have devoted an unusual amount of time to statistical problems that have been referred to the department by the different divisions of the College.

The staff has continued its bi-weekly lectures on advanced work in mathematics, throughout the year. Other departments of the College, as well as the Department of Mathematics, have availed themselves of these lectures.

Beginning with the fall term the department will offer mathematics as a major subject in the Applied Science Division. This will afford the members of the staff an inspiration to push forward in certain lines of mathematics in which they are working.

The total number of students taking mathematics during the year was 1,808, divided among the different terms as follows: Fall, 627; winter, 573; spring, 511; summer, 97. The total number of class periods for the year was 417, divided among the different terms as follows: Fall, 125; winter, 124; spring, 110; summer, 58.

Respectfully submitted,
L. C. PLANT,
Professor of Mathematics.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF MILITARY SCIENCE.

President David Friday,
Sir:

1. PERSONNEL.

The Military Department opened the year with seven officers on duty, nine noncommissioned officers and twenty privates. The privates were mostly on duty with the cavalry unit caring for the horses. The close of the year saw the addition of one captain to the artillery and the relief of one major of cavalry. The organization is therefore in good condition, with two officers for each unit and one as the administrative head.

2. EQUIPMENT.

The material for instruction purposes is all that could be desired save in one particular, the addition of more trophies to the Military Museum which now is practically complete in its historical development of firearms. The loan or donation of modern weapons, taken from European battlefields, has been asked from the War Department but they are hindered by lack of Congressional action.

3. BUILDINGS.

Space for adequate instruction is decidedly lacking. The infantry and artillery are particularly handicapped. Last fall and early winter when theoretical instruction was necessitated by inclement weather, classes had to be held in the large toilet room and in the old rubbing room in the basement, in the gun room, the laboratory at the gym and its lecture room, as well as on the armory floor. The gun shed was caring for at least three classes at one time. A new gun shed of larger dimensions and a new armory are urgently needed to take care of the steady growth of the department.

4. INSTRUCTION.

The year began with an active enrollment of about 650, and ended with 500 at the annual inspection. Under advice of the President, students who served in the World War are given liberal credits and therefore, as each freshman class enters, there will be a decreasingly small number of excuses. In the advanced elective work, 75 students enrolled, resulting in much friction with other classes. Remedial action has been proposed to the President, and is now waiting his pleasure. Judging from preliminary signing of contracts for next year, we will have about 125 students in the advanced course next October. Twenty students received their commissions in the Officers Reserve Corps on graduation day.

5. OUTSIDE ACTIVITIES.

A Girls' Rifle Club was organized again this year, 128 signing up. Gold and silver medals were given as prizes and the winners were in attendance at the annual banquet. Intercollegiate competitions were also held—four of them—of which two were won and two lost.

The Men's Club was organized, 300 joining. The prizes were gold, silver and bronze medals, six sweaters, a banquet and a silver fraternity cup.

All vacant hours from Monday morning to Saturday noon, when no regular classes were in session on the floor, were open to the rifle club from the middle of November to the end of the winter term. Intercollegiate matches for the men were held, both National Rifle Association and corps area and also interfraternity for the loving cup.

Practically every Friday and Saturday night during all three terms the Armory floor was taken by student organizations for dances. The department staff gave one ball in the fall term, the department students gave the annual Military Ball in the gymnasium, and a dance was given for the Inspecting Board the last of May. During the winter term, the first four nights of each week were devoted to rifle competitions.

6. THE BAND.

The band would be stronger in every way if the Board would let it be fully known that it is a MILITARY band and require ALL concerts and other public appearances to be in proper uniform. The wearing of civilian clothes in public performances does not add to the military reputation of the band. It is believed that sometime during the next year, a special request will have to be made for uniforms, repairs and replacements as the uniforms have now been in use the better part of three years.

7. DISCIPLINE.

No cases have come before the Commandant during the past year. The known support of the President and the willingness of the Commandant to fully discuss with a dissatisfied student all phases of his troubles, have resulted in a clean sheet. The active support of Dr. Reynolds in weeding out fake physical disability cases is also cause for congratulation.

As a great aid to discipline next year, it is recommended that the Department of Physical Training lay greater stress on physical culture as such, otherwise, setting up exercises, to improve the carriage of the boys. General Bell commented very adversely on the appearance of the boys when inspecting last May. Restoration of the four year physical training requirement and the utilization of cadet officers in training first and second year men in setting up exercises is recommended.

Respectfully submitted,
P. G. WRIGHTSON,
Major U. S. A., P. M. S. & T.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF METEOROLOGY.

President David Friday,
Michigan Agricultural College:

Dear President Friday:

The regular course in Meteorology was conducted, as usual, during the spring term just closed. Fifteen students completed the course.

Students taking this work are given a practical knowledge of the subject so that they understand better the causes and effects of happenings in the atmosphere. They are able to predict weather changes from local conditions with greater accuracy. Superstitions in regard to the connection between moon phases, equinoxes, etc., and the weather, are dispelled. The technical phase of the subject is given much attention.

Very respectfully,
D. A. SEELEY,
Instructor in Meteorology.

East Lansing, Michigan, June 30, 1922.

METEOROLOGICAL TABLES.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, JULY, 1921.

Date.	Temperature.			Precipitation in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	93	64	78	0	Clear	99
2	91	67	79	0	Partly Cloudy	86
3	94	69	82	0	Clear	93
4	97	71	84	0	Partly Cloudy	74
5	96	70	83	0	Partly Cloudy	86
6	95	69	82	1.00	Partly Cloudy	76
7	92	69	80	0.03	Clear	95
8	89	69	79	0.01	Partly Cloudy	47
9	85	67	76	T.	Partly Coudy	73
10	86	65	76	0	Partly Cloudy	88
11	91	64	78	0	Clear	97
12	93	66	80	0	Clear	100
13	93	66	80	0	Clear	98
14	92	69	80	0.88	Partly Cloudy	66
15	85	60	72	0	Clear	99
16	86	55	70	0	Partly Cloudy	97
17	88	62	75	T.	Partly Cloudy	70
18	95	70	82	0.27	Cloudy	63
19	88	67	78	0.12	Partly Cloudy	69
20	83	59	71	0	Clear	100
21	84	53	68	0	Clear	100
22	86	54	70	0	Partly Cloudy	89
23	90	59	74	0	Clear	92
24	91	63	77	0	Clear	94
25	89	67	78	T.	Partly Cloudy	47
26	92	69	80	0.07	Partly Cloudy	71
27	88	73	80	0.12	Cloudy	40
28	86	68	77	0.11	Partly Cloudy	67
29	84	65	74	T.	Partly Cloudy	82
30	91	60	76	T.	Partly Cloudy	89
31	75	55	65	0	Partly Cloudy	63

Mean highest temperature	89.3
Mean lowest temperature	64.6
Mean temperature for month	77.0
Total precipitation for month	2.61

Weather.

Number days clear	11
Partly cloudy	18
Cloudy	2
With 0.01 inch or more of precipitation	9

Sunshine.

Number hours sunshine	376.9
Possible hours sunshine	461.9
Percentage of possible	81

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863	....	....
1864	74.5	1.25
1865	65.6	3.91
1866	71.7	4.19
1867	71.6	1.78
1868	77.2	1.11
1869	70.4	5.77
1870	74.4	8.02
1871	70.6	3.10
1872	74.9	3.36
1873	70.8	5.12
1874	72.0	2.56
1875	69.7	2.42
1876	72.5	2.10
1877	71.4	2.25
1878	73.0	2.96
1879	74.0	2.19
1880	68.0	6.27
1881	73.1	1.81
1882	67.5	2.32
1883	68.9	1.27
1884	68.0	12.60
1885	72.7	2.52
1886	70.7	0.65
1887	75.5	1.50
1888	70.5	2.40
1889	70.2	3.41
1890	71.1	0.92
1891	65.3	1.88
1892	70.3	2.00
1893	71.5	1.86
1894	73.2	0.86
1895	70.5	1.47
1896	71.8	6.73
1897	73.8	8.49
1898	70.0	1.34
1899	69.8	2.11
1900	69.6	4.15
1901	74.2	5.08
1902	70.6	7.13
1903	67.9	3.79
1904	69.2	1.97
1905	69.8	5.75
1906	70.8	2.23
1907	70.0	4.30
1908	73.2	1.03
1909	70.0	2.56
1910	71.0	1.53
1911	71.3	1.65
1912	69.6	5.06
1913	70.8	2.85
1914	71.0	1.65
1915	67.9	5.17
1916	76.1	0.09
1917	70.0	3.06
1918	69.2	1.96
1919	72.4	1.69
1920	67.3	3.01
1921	77.0	2.61

BAROMETER—Mean, 29.98 inches; highest, 30.16 inches, on 22d; lowest, 29.66 inches, on 30th.

TEMPERATURE—Highest, 97°, on 4th; lowest, 53°, on 21st.; greatest daily range, 32°, on 22d; least daily range, 15°, on 27th; normal temperature, 70.9°; departure, +6.1°; accumulated departure since January 1, +1208°; average daily departure since January 1, +5.7° highest in 36 years, 102°; lowest, 37°.

PRECIPITATION (in inches)—Total this month, 2.61; normal, 3.22; departure, −0.61; since January 1st, −3.13; greatest amount in 24 hours, 1.00, on 6th; total snowfall, 0.0 in.

WIND—Prevailing direction, southwest; total movement, 2,711 miles; average hourly velocity, 3.6 miles; maximum velocity, 32 miles per hour, from northwest in 14th.

DATES OF—Auroras, 0; hail, 0; sleet, 0; fog—dense, 0; thunderstorms, 4, 5, 6, 7, 8, 14, 18, 26, 27, 28, 30; halos—solar, 25; halos—lunar, 0; frost—killing, 0; heavy, 0; light, 0.

DEWEY A. SEELEY,
Meteorologist.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, AUGUST, 1921.

Date.	Temperature.			Precipitation in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	74	52	63	0.20	Cloudy	3
2	67	57	62	0.13	Cloudy	0
3	80	53	66	0	Clear	98
4	81	55	68	0	Partly Cloudy	79
5	84	62	73	0	Clear	96
6	85	62	74	T.	Partly Cloudy	48
7	77	54	66	T.	Partly Cloudy	62
8	76	51	64	0	Partly Cloudy	90
9	84	54	69	0	Partly Cloudy	84
10	80	62	71	T.	Cloudy	10
11	74	63	68	0.14	Cloudy	13
12	77	60	68	0	Partly Cloudy	43
13	87	58	72	0.43	Partly Cloudy	86
14	73	52	62	T.	Clear	94
15	76	45	60	0	Clear	100
16	79	56	68	0	Cloudy	25
17	80	62	71	2.26	Cloudy	24
18	80	60	70	0	Partly Cloudy	57
19	85	55	70	0.63	Clear	86
20	78	53	66	0	Partly Cloudy	61
21	73	46	60	0	Clear	96
22	72	47	60	0	Partly Cloudy	66
23	78	50	64	0	Clear	100
24	85	53	69	0	Partly Cloudy	75
25	85	60	72	0	Partly Cloudy	99
26	86	58	72	0	Cloudy	49
27	73	66	70	1.39	Cloudy	0
28	80	69	74	T.	Cloudy	10
29	86	70	78	0	Partly Cloudy	78
30	88	70	79	0	Partly Cloudy	70
31	88	69	78	T.	Partly Cloudy	61

Mean highest temperature	79.7
Mean lowest temperature	57.5
Mean temperature for month	68.6
Total precipitation for month	5.18

WEATHER.

Number days clear	7
Partly cloudy	15
Cloudy	9
With 0.01 inch or more of precipitation	7

SUNSHINE.

Number hours sunshine	258.7
Possible hours sunshine	430.7
Percentage of possible	60

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863	....	3.00
1864	70.7	0.39
1865	65.8	3.38
1866	62.6	3.44
1867	69.8	1.74
1868	70.3	2.42
1869	70.6	4.85
1870	70.1	4.53
1871	71.2	1.42
1872	71.2	4.18
1873	69.5	0.80
1874	69.4	1.28
1875	65.5	1.47
1876	71.6	1.28
1877	68.5	6.57
1878	70.2	1.85
1879	70.0	1.61
1880	68.6	6.02
1881	72.7	1.63
1882	69.5	5.72
1883	64.9	0.18
1884	66.9	1.30
1885	63.6	6.75
1886	69.3	4.69
1887	68.0	0.89
1888	67.6	1.87
1889	68.6	0.68
1890	65.4	3.60
1891	67.9	4.82
1892	68.3	5.12
1893	68.1	0.56
1894	68.8	0.00
1895	71.2	4.64
1896	70.0	4.73
1897	65.9	1.69
1898	69.0	2.73
1899	71.4	0.70
1900	73.3	2.98
1901	68.4	2.49
1902	64.2	0.68
1903	64.3	6.73
1904	65.9	3.26
1905	69.6	3.92
1906	73.5	4.35
1907	65.5	2.87
1908	68.4	3.99
1909	71.0	1.61
1910	68.2	1.76
1911	68.2	1.48
1912	65.7	2.19
1913	69.4	5.60
1914	68.9	3.33
1915	63.4	4.63
1916	71.0	1.58
1917	67.0	1.47
1918	72.2	1.44
1919	67.3	4.03
1920	67.9	2.00
1921	68.6	5.18

BAROMETER—Mean, 30.04 inches; highest, 30.36 inches, on 21st; lowest, 29.54 inches, on 17th.

TEMPERATURE—Highest, 88°, on 31st; lowest, 45°, on 15th; greatest daily range, 32°, on 24th; least daily range, 7°, on 27th; normal temperature, 68.4°; departure, +0.2°; accumulated departure since January 1, +1216°; average daily departure since January 1, +5.0°; highest in 36 years, 102°; lowest, 32°.

PRECIPITATION (in inches)—Total this month, 5.18; normal, 2.63; departure, +2.55; since January 1st, −0.58; greatest amount in 24 hours, 2.26, on 17th; total snowfall, 0.0 in.

WIND—Prevailing direction, southwest; total movement, 3,055 miles; average hourly velocity, 4.1 miles; maximum velocity, 18 miles per hour, from northwest on 17th.

DATES OF—Auroras, 0; hail, 0; sleet, 0; fog—dense, 26, 28; thunderstorms, 6, 13, 17, 19, 27, 30; halos—solar, 9, 22; halos—lunar, 15; frost—killing, 0; heavy, 0; light, 0.

DEWEY A. SEELEY,
Meteorologist.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, SEPTEMBER, 1921.

Date.	Temperature.			Precipitation in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	89	69	79	0	Partly Cloudy	63
2	87	69	78	T.	Partly Cloudy	62
3	85	68	76	T.	Cloudy	30
4	87	68	78	0.06	Partly Cloudy	54
5	79	57	68	0.17	Partly Cloudy	37
6	80	51	66	0	Clear	100
7	82	53	68	0	Clear	100
8	83	55	69	0	Partly Cloudy	77
9	86	58	72	0	Partly Cloudy	83
10	82	59	70	0.17	Cloudy	39
11	76	62	69	0.03	Cloudy	10
12	76	52	64	0	Clear	90
13	78	50	64	0	Partly Cloudy	79
14	81	60	70	0.01	Cloudy	13
15	72	57	64	0	Cloudy	5
16	68	57	62	0.04	Cloudy	0
17	78	58	68	0.13	Cloudy	18
18	68	47	58	0	Cloudy	9
19	72	41	56	0.04	Partly Cloudy	46
20	73	58	66	1.14	Cloudy	0
21	73	60	66	0.15	Partly Cloudy	45
22	81	57	69	0	Clear	100
23	77	49	63	0	Clear	100
24	80	55	68	0.06	Cloudy	60
25	68	44	56	0.07	Partly Cloudy	95
26	70	40	55	0	Clear	100
27	73	44	58	0.10	Partly Cloudy	81
28	77	53	65	0	Clear	100
29	87	65	76	0.10	Clear	97
30	65	44	54	0.37	Cloudy	22
31						

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863		0.89
1864	59.6	3.53
1865	67.7	4.79
1866	55.8	5.80
1867	56.6	1.42
1868	58.8	2.95
1869	63.5	1.43
1870	63.7	2.85
1871	59.1	0.79
1872	62.0	5.21
1873	67.4	3.50
1874	62.8	1.27
1875	58.5	2.89
1876	56.3	3.65
1877	61.3	1.38
1878	63.2	3.41
1879	56.2	3.19
1880	55.8	3.10
1881	69.7	2.91
1882	59.9	0.67
1883	56.4	2.34
1884	65.1	3.34
1885	58.9	3.75
1886	62.1	5.40
1887	58.9	4.72
1888	57.8	1.89
1889	61.2	0.79
1890	57.7	1.67
1891	65.1	1.10
1892	60.8	2.17
1893	58.4	1.84
1894	63.7	2.59
1895	66.6	0.85
1896	57.6	6.73
1897	62.9	0.80
1898	63.3	3.00
1899	57.0	2.14
1900	63.2	0.89
1901	61.7	1.67
1902	58.7	5.88
1903	61.0	2.86
1904	62.0	2.35
1905	63.8	3.21
1906	67.5	0.76
1907	61.8	4.68
1908	66.4	0.65
1909	60.4	1.51
1910	60.2	2.74
1911	61.5	5.05
1912	62.7	3.33
1913	61.0	1.53
1914	60.3	2.65
1915	63.2	6.55
1916	60.4	2.17
1917	58.6	4.60
1918	54.2	2.88
1919	63.8	2.61
1920	64.2	1.62
1921	66.6	2.64

Mean highest temperature	77.8
Mean lowest temperature	55.3
Mean temperature for month	66.1
Total precipitation for month	2.64

WEATHER.

Number days clear	8
Partly cloudy	11
Cloudy	11
With 0.01 inch or more of precipitation	15

SUNSHINE.

Number hours sunshine	213.4
Possible hours sunshine	374.8
Percentage of possible	57

BAROMETER—Mean, 29.98 inches; highest, 30.33, on 13th; lowest, 29.40, inches on 30th.

TEMPERATURE—Highest, 89°, on 1st; lowest, 40°, on 26th; greatest daily range, 31°, on 19th; least daily range, 11°, on 16th; normal temperature, 61.6°; departure, +5.0°; accumulated departure since January 1, +1363°; average daily departure since January 1, +5.0°; highest in 36 years, 99°; lowest, 21°.

PRECIPITATION (in inches)—Total this month, 2.64; normal, 2.62; departure, +0.02; since January 1st, −0.56; greatest amount in 24 hours, 1.18, on 19th and 20th; total snowfall, 0.0 in.

WIND—Prevailing direction, southwest; total movement, 3,324 miles; average hourly velocity, 4.6 miles; maximum velocity, 21 miles per hour from east on 29th.

DATES OF—Auroras, 1, 2, 28; hail, 0; sleet, 0; fog—dense, 11; thunderstorms, 2, 3, 4, 10, 17, 20, 21, 29, 30; halos—solar, 10, 19, 24; halos—lunar, 0; frost—killing, 0; heavy, 0; light, 0.

DEWEY A. SEELEY,
Meteorologist.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, OCTOBER, 1921.

Date.	Temperature.			Precipitation in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	71	43	57	0	Clear	100
2	57	49	53	0.32	Cloudy	0
3	58	39	48	0.04	Partly Cloudy	53
4	57	37	47	0	Partly Cloudy	72
5	64	35	50	0	Clear	100
6	69	41	55	0.52	Clear	82
7	48	37	42	0.76	Cloudy	0
8	48	36	42	0.03	Cloudy	23
9	61	39	50	0.16	Partly Cloudy	61
10	57	42	50	0.49	Partly Cloudy	58
11	47	33	40	0.11	Cloudy	0
12	47	30	38	0.03	Partly Cloudy	55
13	60	29	44	0	Clear	100
14	64	37	50	0	Clear	100
15	66	39	52	0	Clear	100
16	72	48	60	0.13	Clear	100
17	75	55	65	0.01	Clear	89
18	63	50	56	0.03	Cloudy	1
19	60	41	50	0.11	Partly Cloudy	53
20	57	35	46	0.02	Partly Cloudy	38
21	60	31	46	0	Clear	100
22	64	39	52	0	Clear	100
23	59	33	46	0	Clear	90
24	71	44	58	0	Clear	100
25	56	39	48	0	Partly Cloudy	77
26	58	36	47	0	Partly Cloudy	50
27	58	48	53	0.02	Cloudy	0
28	68	47	58	0	Clear	90
29	62	48	55	T.	Cloudy	4
30	58	50	54	0.05	Cloudy	0
31	59	47	53	0.02	Cloudy	0

Mean highest temperature........ 60.5
Mean lowest temperature........ 40.5
Mean temperature for month........ 50.5
Total precipitation for month........ 2.85

WEATHER.

Number days clear........ 13
Partly cloudy........ 9
Cloudy........ 9
With 0.01 inch or more of precipitation........ 17

SUNSHINE.

Number hours sunshine........ 198.8
Possible hours sunshine........ 341.9
Percentage of possible........ 58

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863	....	1.04
1864	45.7	1.86
1865	46.5	2.76
1866	49.5	3.57
1867	50.6	2.11
1868	45.2	1.11
1869	40.8	1.72
1870	52.5	2.29
1871	53.9	1.43
1872	47.4	0.67
1873	44.7	1.91
1874	49.1	0.49
1875	42.9	5.81
1876	43.7	1.26
1877	50.8	5.69
1878	48.3	1.99
1879	57.3	1.57
1880	46.2	2.84
1881	52.5	5.56
1882	52.7	2.64
1883	46.2	3.66
1884	50.9	5.73
1885	45.0	3.03
1886	52.4	0.95
1887	45.0	1.86
1888	45.7	3.00
1889	44.2	0.65
1890	49.1	4.56
1891	48.8	0.82
1892	48.3	0.78
1893	49.7	3.61
1894	49.8	1.91
1895	45.0	1.41
1896	44.6	1.06
1897	53.1	2.15
1898	49.6	3.55
1899	53.2	2.68
1900	56.6	2.77
1901	49.6	4.01
1902	49.6	1.53
1903	51.0	2.01
1904	48.6	1.90
1905	50.9	1.75
1906	49.2	2.36
1907	46.0	2.22
1908	51.6	0.82
1909	46.2	0.71
1910	51.8	2.27
1911	48.0	5.00
1912	50.4	3.44
1913	50.2	3.30
1914	54.6	2.81
1915	51.1	0.70
1916	49.7	2.53
1917	41.2	3.44
1918	52.6	3.21
1919	53.3	2.90
1920	57.8	1.37
1921	50.5	2.85

BAROMETER—Mean, 29.96 inches; highest, 30.39 inches, on 14th; lowest, 29.52 inches, on 19th.

TEMPERATURE—Highest, 75°, on 17th; lowest, 29°, on 13th; greatest daily range, 31°, on 13th; least daily range, 8°, on 30th; normal temperature, 49.0°; departure, +1.5°; accumulated departure since January 1, +1408°; average daily departure since January 1, +4.6°; highest in 36 years, 90°; lowest, 10°.

PRECIPITATION (in inches)—Total this month, 2.85; normal, 2.23; departure, +0.62; since January 1, +0.06; greatest amount in 24 hours, 1.28, on 6th and 7th; total snowfall, T. in.

WIND—Prevailing direction, southwest; total movement, 4,569 miles; average hourly velocity, 6.1 miles; maximum velocity, 20 miles per hour from northwest on 12th.

DATES OF—Auroras, 7; hail, 0; sleet, 0; fog—dense, 31; thunderstorms, 16; halos—solar, 1, 26, 29; halos—lunar, 25; frost—killing, 13; heavy, 0; light, 5, 12.

DEWEY A. SEELEY,
Meteorologist.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, NOVEMBER, 1921.

Date.	Temperature.			Precipitation in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	50	33	42	0	Partly Cloudy	74
2	51	28	40	0	Partly Cloudy	90
3	49	30	40	T.	Cloudy	29
4	55	34	44	0.01	Cloudy	20
5	41	27	34	0	Cloudy	10
6	38	31	34	0.03	Cloudy	0
7	42	30	36	T.	Cloudy	3
8	31	27	29	1.64	Cloudy	0
9	34	26	30	0.07	Cloudy	0
10	36	16	26	0	Cloudy	1
11	34	21	28	0.02	Cloudy	20
12	32	13	22	0	Partly Cloudy	82
13	34	25	30	0.18	Cloudy	0
14	36	31	34	T.	Cloudy	16
15	36	31	34	0	Cloudy	5
16	41	31	36	T.	Cloudy	4
17	59	37	48	0.04	Cloudy	0
18	58	48	53	0.89	Cloudy	0
19	51	33	42	0.76	Cloudy	0
20	38	30	34	0	Partly Cloudy	30
21	42	31	36	0	Cloudy	3
22	33	26	30	T.	Cloudy	0
23	35	26	30	T.	Cloudy	0
24	37	25	31	0.06	Cloudy	0
25	41	24	32	0	Partly Cloudy	68
26	43	36	40	0.30	Cloudy	0
27	44	37	40	0	Cloudy	0
28	37	29	33	0.03	Cloudy	0
29	39	29	34	0	Cloudy	0
30	41	27	34	0.03	Cloudy	24
31	....	....	....	....	....	....

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863	....	0.40
1864	37.9	4.12
1865	38.6	0.63
1866	37.9	2.60
1867	40.4	1.77
1368	36.8	2.44
1869	32.1	1.93
1870	38.4	0.91
1871	32.0	1.25
1872	29.8	0.98
1873	28.5	2.03
1874	35.0	1.61
1875	33.0	1.11
1876	36.3	0.91
1877	35.2	3.67
1878	36.3	2.16
1879	38.2	4.55
1880	27.5	2.32
1881	38.2	4.09
1882	36.3	1.83
1883	38.1	3.98
1884	34.1	1.84
1885	37.2	2.90
1886	33.9	1.48
1887	35.7	2.28
1888	38.5	3.12
1889	37.4	2.67
1890	39.1	2.30
1891	34.0	3.34
1892	34.2	1.84
1893	35.6	2.19
1894	32.5	0.97
1895	35.4	3.87
1896	37.1	1.05
1897	36.5	2.94
1898	33.1	2.72
1899	39.7	1.72
1900	35.3	5.10
1901	32.8	1.21
1902	43.0	2.46
1903	34.0	1.45
1904	40.0	0.04
1905	35.8	2.25
1906	37.0	2.66
1907	36.0	1.83
1908	38.2	1.82
1909	44.5	3.74
1910	34.0	1.37
1911	33.8	3.40
1912	38.6	2.86
1913	41.7	2.38
1914	37.6	1.40
1915	39.8	2.23
1916	38.8	1.68
1917	35.8	0.82
1918	40.4	3.22
1919	35.7	2.44
1920	36.6	2.29
1921	35.2	4.06

Mean highest temperature	41.3
Mean lowest temperature	29.1
Mean temperature for month	35.2
Total precipitation for month	4.06

WEATHER.

Number days clear	0
Partly cloudy	5
Cloudy	25
With 0.01 inch or more of precipitation	13

SUNSHINE.

Number hours sunshine	47.5
Possible hours sunshine	292.1
Percentage of possible	16

BAROMETER—Mean, 30.05 inches; highest, 30.52 inches, on 20th; lowest, 29.63, on 19th.

TEMPERATURE—Highest, 59°, on 17th; lowest, 13°, on 12th; greatest daily range, 23°, on 2d; least daily range, 4°, on 8th; normal temperature, 36.8°; departure, −1.6°; accumulated departure since January 1, +1360°; average daily departure since January 1, +4.1°; highest in 36 years, 72°; lowest, 0°.

PRECIPITATION (in inches)—Total this month, 4.06; normal, 2.41; departure, +1.65; since January 1, +1.71; greatest amount in 24 hours, 1.64, on 8th; total snowfall, 21.8 in.

WIND—Prevailing direction, northeast; total movement, 4,624 miles; average hourly velocity, 6.4 miles; maximum velocity, 30 miles per hour from northest on 1st.

DATES OF—Auroras, 0; hail, 0; sleet, 6, 23; fog—dense, 16, 17, 24, 26, 27; thunderstorms, 0; halos—solar, 2, 11, 25; halos—lunar, 11, 15; frost—killing, 0; heavy, 0; light, 0.

DEWEY A. SEELEY,
Meteorologist.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, DECEMBER, 1921.

Date.	Temperature. Highest.	Temperature. Lowest.	Temperature. Mean.	Precipitation in inches.	Character of day.	Percentage of possible sunshine.
1	53	34	44	0.30	Cloudy	3
2	54	31	42	0.48	Cloudy	1
3	32	29	30	0	Cloudy	0
4	38	25	32	0.03	Partly Cloudy	48
5	35	27	31	0.03	Cloudy	11
6	39	24	32	0	Partly Cloudy	27
7	33	23	28	0	Cloudy	1
8	32	27	30	T.	Cloudy	0
9	30	26	28	0	Cloudy	0
10	44	30	37	T.	Cloudy	27
11	38	29	34	0.09	Cloudy	11
12	32	28	30	0.28	Cloudy	0
13	32	26	29	0.06	Cloudy	0
14	33	24	28	0.03	Cloudy	23
15	34	21	28	0.01	Partly Cloudy	69
16	46	30	38	0.69	Cloudy	0
17	53	32	42	1.43	Cloudy	0
18	32	22	27	0.05	Partly Cloudy	51
19	32	21	26	0	Partly Cloudy	37
20	40	23	32	T.	Partly Cloudy	67
21	27	9	18	T.	Partly Cloudy	47
22	23	8	16	T.	Cloudy	0
23	28	23	26	0.01	Cloudy	0
24	24	10	17	0.03	Cloudy	6
25	24	3	14	T.	Partly Cloudy	49
26	27	15	21	T.	Cloudy	0
27	27	12	20	T.	Cloudy	0
28	34	13	24	0	Cloudy	0
29	33	13	23	T.	Partly Cloudy	80
30	36	20	28	T.	Partly Cloudy	67
31	38	23	30	0.02	Cloudy	0

Mean highest temperature	34.9
Mean lowest temperature	22.0
Mean temperature for month	28.4
Total precipitation for month	3.54

WEATHER.

Number days clear	0
Partly cloudy	10
Cloudy	21
With 0.01 inch or more of precipitation	15

SUNSHINE.

Number hours sunshine	56.4
Possible hours sunshine	280.8
Percentage of possible	20

This month since 1863. Year.	Mean temperature.	Total precipitation.
1863	....	1.71
1864	24.4	3.20
1865	26.7	1.43
1866	25.5	1.90
1867	25.3	1.34
1868	21.2	1.35
1869	28.2	2.11
1870	24.8	2.57
1871	21.1	1.76
1872	15.7	1.06
1873	29.5	3.02
1874	27.0	0.37
1875	31.6	2.80
1876	15.2	1.29
1877	36.6	1.03
1878	21.3	2.27
1879	27.5	3.55
1880	22.1	0.85
1881	34.3	1.75
1882	24.8	0.88
1883	26.4	1.28
1884	24.7	4.15
1885	27.8	2.14
1886	19.7	1.56
1887	27.3	3.32
1888	30.4	1.20
1889	36.8	2.61
1890	26.4	1.12
1891	34.6	1.47
1892	25.6	1.52
1893	27.6	2.28
1894	30.1	0.93
1895	28.5	5.39
1896	28.1	0.80
1897	25.6	2.02
1898	24.8	1.42
1899	25.0	1.51
1900	26.7	0.50
1901	21.6	3.00
1902	24.8	2.89
1903	19.7	1.75
1904	21.7	1.42
1905	30.2	2.54
1906	26.8	1.85
1907	22.7	4.19
1908	26.4	2.08
1909	23.0	2.91
1910	21.6	1.28
1911	31.1	1.58
1912	31.0	1.20
1913	31.8	0.55
1914	21.6	1.57
1915	24.8	1.01
1916	22.7	2.11
1917	19.1	0.74
1918	32.9	3.61
1919	19.4	0.86
1920	30.6	3.94
1921	28.4	3.54

BAROMETER—Mean, 30.00 inches; highest, 30.51 inches, on 25th; lowest, 29.17 inches, on 2d.

TEMPERATURE—Highest, 54°, on 2d; lowest, 3°, on 25th; greatest daily range, 23°, on 2d; least daily range, 3°, on 3d; normal temperature, 26.8°; departure, +1.6°; accumulated departure since January 1, +1415°; average daily departure since January 1, +3.9°; highest in 36 years, 62°; lowest, −24°.

PRECIPITATION (in inches)—Total this month, 3.54; normal, 2.08; departute, +1.46; since January 1, +3.17; greatest amount in 24 hours, 1.43, on 17th; total snowfall, 8.3 in.

WIND—Prevailing direction, northwest; total movement, 5,622 miles; average hourly velocity, 7.6 miles; maximum velocity, 28 miles per hour from northwest on 31st.

DATES OF—Auroras, 0; hail, 0; sleet, 18, 23; fog—dense, 0; thunderstorms, 0; halos—solar, 4, 14, 15, 22, 30; halos—lunar, 15; frost—killing, —; heavy, —; light, —.

DEWEY A. SEELEY,
Meteorologist.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, JANUARY, 1922.

Date.	Temperature.			Precipitation in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	23	8	16	0.01	Cloudy	29
2	25	8	16	0	Cloudy	3
3	43	23	33	T.	Partly Cloudy	68
4	48	30	39	0.74	Cloudy	0
5	36	18	27	T.	Cloudy	0
6	22	15	18	0.01	Cloudy	0
7	32	11	22	0	Partly Cloudy	67
8	40	26	33	T.	Partly Cloudy	37
9	44	27	36	0	Clear	100
10	39	25	32	0	Partly Cloudy	78
11	34	18	26	0.01	Cloudy	11
12	20	13	16	0.02	Cloudy	20
13	24	14	19	0.05	Cloudy	22
14	38	7	22	T.	Cloudy	42
15	35	14	24	0.03	Cloudy	1
16	22	13	18	T.	Cloudy	18
17	37	12	24	0.03	Partly Cloudy	82
18	29	23	26	0.21	Cloudy	0
19	31	11	21	0.05	Cloudy	3
20	23	2	12	0.02	Partly Cloudy	72
21	29	15	22	0.04	Cloudy	19
22	24	–4	10	0.01	Partly Cloudy	68
23	12	–4	4	T.	Clear	90
24	15	–7	4	0	Clear	100
25	18	–12	3	0	Clear	100
26	24	0	12	0	Clear	100
27	27	8	18	0	Partly Cloudy	74
28	31	7	19	0	Clear	100
29	36	7	22	0	Clear	87
30	39	14	26	0	Partly Cloudy	92
31	45	18	32	0	Partly Cloudy	75

Mean highest temperature	30.5
Mean lowest temperature	11.6
Mean temperature for month	21.0
Total precipitation for month	1.23

WEATHER.

Number days clear	7
Partly cloudy	10
Cloudy	14
With 0.01 inch or more of precipitation	13

SUNSHINE.

Number hours sunshine	148.5
Possible hours sunshine	292.5
Percentage of possible	51

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863	....	....
1864	22.3	0.94
1865	21.1	0.65
1866	21.2	2.03
1867	17.6	1.68
1868	19.0	1.47
1869	29.4	0.87
1870	25.4	1.93
1871	24.8	3.95
1872	21.6	0.42
1873	15.9	2.98
1874	27.7	3.53
1875	12.9	1.81
1876	30.2	1.63
1877	18.1	1.33
1878	29.1	1.12
1879	19.2	0.49
1880	37.1	2.67
1881	17.0	2.27
1882	24.9	1.47
1883	14.4	1.53
1884	15.5	1.23
1885	15.3	2.70
1886	18.8	2.66
1887	18.2	3.25
1888	15.4	2.18
1889	28.0	1.53
1890	31.5	2.31
1891	26.7	0.82
1892	19.2	0.96
1893	14.8	1.78
1894	26.9	1.37
1895	17.5	1.04
1896	24.6	0.79
1897	22.3	4.17
1898	24.9	3.07
1899	21.7	2.03
1900	25.6	1.17
1901	22.2	1.51
1902	20.5	0.43
1903	20.7	1.20
1904	14.4	2.82
1905	18.2	1.07
1906	31.8	1.99
1907	23.2	3.97
1908	23.8	1.89
1909	26.6	2.16
1910	23.4	2.52
1911	25.2	1.43
1912	9.2	0.80
1913	26.2	3.10
1914	27.0	2.98
1915	20.4	1.54
1916	27.6	3.11
1917	21.0	1.55
1918	10.2	2.08
1919	28.5	0.36
1920	13.2	1.34
1921	29.2	0.41
1922	21.0	1.23

BAROMETER—Mean, 30.17 inches; highest, 30.80 inches, on 24th; lowest, 29.44 inches, on 4th.

TEMPERATURE—Highest, 48°, on 4th; lowest,—12°, on 25th; greatest daily range, 31°, on 14th; least daily range, 6°, on 18th; normal temperature, 22.7°; departure, —1.7°; accumulated departure since January 1, —51°; average daily departure since January 1, —1.7; highest in 37 years, 63°; lowest, —26°.

PRECIPITATION (in inches)—Total this month, 1.23; normal, 2.09; departure, —0.86; since January 1, —0.86; greatest amount in 24 hours, 0.74, on 4th; total snowfall, 5.9 in.

WIND—Prevailing direction, southwest; total movement, 5,498 miles; average hourly velocity, 7.4 miles; maximum velocity, 27 miles per hour from southwest on 4th.

DATES OF—Auroras, 0; hail, 0; sleet, 0; fog—dense, 29; thunderstorms, 0; halos—solar, 14, 27, 31; halos—lunar, 10, 17; frost—killing, —; heavy, —; light, —.

DEWEY A. SEELEY,
Meteorologist.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, FEBRUARY, 1922.

Date.	Temperature.			Precipitation in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	41	30	36	0.14	Cloudy	2
2	36	20	28	0.02	Cloudy	7
3	25	21	23	0.02	Cloudy	0
4	33	22	28	0	Partly Cloudy	48
5	36	23	30	0.10	Cloudy	0
6	32	23	28	T.	Cloudy	7
7	27	17	22	T.	Cloudy	48
8	36	19	28	0	Partly Cloudy	88
9	42	30	36	0	Partly Cloudy	38
10	48	28	38	T.	Partly Cloudy	77
11	40	18	29	0	Partly Cloudy	92
12	20	14	17	0.11	Cloudy	0
13	22	6	14	T.	Partly Cloudy	52
14	29	8	18	T.	Clear	80
15	20	5	12	T.	Partly Cloudy	61
16	15	0	8	T.	Partly Cloudy	81
17	29	2	16	0	Cloudy	10
18	39	29	34	T.	Cloudy	24
19	45	32	38	T.	Cloudy	0
20	32	20	26	0	Partly Cloudy	42
21	34	19	26	0.24	Cloudy	31
22	51	32	42	0.08	Cloudy	2
23	55	12	34	0.21	Cloudy	0
24	26	9	18	0	Clear	100
25	28	20	24	0.01	Cloudy	2
26	35	25	30	0.03	Partly Cloudy	47
27	36	18	27	0.01	Cloudy	20
28	25	13	19	0	Partly Cloudy	78
29						
30						
31						

Mean highest temperature	33 5
Mean lowest temperature	18.4
Mean temperature for month	26.0
Total precipitation for month	0.97

Weather.

Number days clear	2
Partly cloudy	11
Cloudy	15
With 0.01 inch or more of precipitation	11

Sunshine.

Number hours sunshine	109 8
Possible hours sunshine	295 2
Percentage of possible	37

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863		
1864	27.3	0.27
1865	27.6	1.76
1866	22.7	2.28
1867	30.9	3.23
1868	18.7	1.28
1869	26.7	2.95
1870	24.2	1.20
1871	25 6	1.73
1872	21.3	0.46
1873	19 1	0.77
1874	25.5	1 55
1875	8 0	2.20
1876	27.4	3.04
1877	32 3	0.00
1878	28 1	2.74
1879	20.4	1.43
1880	29.2	1.62
1881	21.6	3.77
1882	35.1	2.28
1883	19.8	4.50
1884	23 4	3.69
1885	8 9	0.73
1886	22.3	1.35
1887	24.3	5.71
1888	22.0	1.70
1889	18.3	1.17
1890	31 5	1.79
1891	26 7	2.20
1892	27.3	1.93
1893	21.3	1.83
1894	21.2	0.53
1895	16.4	0.12
1896	24.3	1.51
1897	26 4	0.67
1898	23.8	1.82
1899	16.8	1.51
1900	17.4	3.44
1901	12.8	1.83
1902	18.6	0.44
1903	20.6	1.58
1904	12.0	3.30
1905	15.8	1.25
1906	23.6	1 12
1907	19.2	0.25
1908	21.6	3.19
1909	28.4	2.36
1910	21.9	2.65
1911	27.6	1.77
1912	15.8	2.04
1913	20.0	1.65
1914	12.7	0.79
1915	29.4	2.10
1916	19.2	0.69
1917	15.5	0.62
1918	21.8	3.04
1919	27.0	1.50
1920	19.8	0.81
1921	28 3	1.25
1922	26 0	0.97

BAROMETER—Mean, 30.08 inches; highest, 30.71 inches, on 28th; lowest, 29.37 inches, on 2d.

TEMPERATURE—Highest, 55°, on 23d; lowest, zero°, on 16th; greatest daily range, 43°, on 23d; least daily range, 4°, on 3d; normal temperature, 21.6°; departure, +4.4°; accumulated departure since January 1, +72°; average daily departure since January 1, +1.2; highest in 37 years, 82°; lowest, −12°.

PRECIPITATION (in inches)—Total this month, 0.97; normal, 2.02; departure, −1.05; since January 1, −1.91; greatest amount in 24 hours, 0.24, on 21st; total snowfall, 4.6 in.

WIND—Prevailing direction, southwest; total movement, 5,282 miles; average hourly velocity, 7.9 miles; maximum velocity, 30 miles per hour from southwest on 23d.

DATES OF—Auroras, 22; hail, 0; sleet, 12; fog—dense, 10, 21, 22; thunderstorms, 21; halos—solar, 8, 10, 17, 18, 20, 26; halos—lunar, 8; frost—killing, —; heavy, —; light, —.

DEWEY A. SEELEY,
Meteorologist.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, MARCH, 1922.

Date.	Temperature.			Precipitation in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	23	15	19	0.14	Cloudy	0
2	35	19	27	0	Partly Cloudy	71
3	42	14	28	0	Clear	100
4	47	20	34	0	Clear	100
5	51	27	39	0	Clear	99
6	53	36	44	0.15	Cloudy	40
7	38	21	30	0.06	Cloudy	0
8	42	25	34	0	Clear	81
9	50	30	40	0	Partly Cloudy	68
10	55	30	42	0.05	Partly Cloudy	56
11	45	29	37	0.37	Clear	80
12	52	26	39	0	Partly Cloudy	90
13	61	34	48	0	Partly Cloudy	79
14	55	33	44	0	Cloudy	40
15	52	29	40	0	Clear	100
16	40	24	32	0	Partly Cloudy	86
17	37	20	28	0	Partly Cloudy	64
18	31	19	25	0.11	Cloudy	0
19	45	30	38	0.53	Cloudy	0
20	43	25	34	0.18	Cloudy	0
21	28	22	25	0.03	Cloudy	21
22	36	17	26	0	Clear	100
23	56	26	41	0	Clear	80
24	47	33	40	0.01	Cloudy	19
25	71	37	54	0	Partly Cloudy	66
26	47	33	40	0.03	Partly Cloudy	57
27	40	33	36	0.10	Cloudy	0
28	51	30	40	0.39	Cloudy	2
29	39	25	32	0	Partly Cloudy	74
30	32	28	30	0.97	Cloudy	0
31	31	28	30	0.57	Cloudy	0

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863	.....	.....
1864	31.7	2.26
1865	37.0	2.79
1866	29.1	3.39
1867	29.7	0.68
1868	37.8	4.65
1869	27.6	1.65
1870	30.3	3.01
1871	38.2	3.91
1872	24.8	2.04
1873	28.3	1.73
1874	32.3	1.79
1875	26.2	1.02
1876	30.6	4.84
1877	24.5	5.60
1878	40.9	3.12
1879	33.2	1.57
1880	35.5	1.70
1881	30.3	2.66
1882	36.0	3.58
1883	24.9	0.71
1884	29.9	3.67
1885	21.3	0.58
1886	31.3	2.63
1887	28.3	1.78
1888	27.0	1.88
1889	37.6	1.22
1890	28.2	1.54
1891	29.3	2.41
1892	29.9	1.31
1893	28.2	2.82
1894	40.1	1.25
1895	27.2	0.27
1896	28.7	1.31
1897	33.0	2.08
1898	37.0	3.59
1899	26.3	3.30
1900	23.6	1.88
1901	31.1	2.94
1902	38.0	3.16
1903	41.0	1.25
1904	30.2	3.45
1905	35.4	3.15
1906	26.2	1.86
1907	38.6	2.84
1908	34.8	2.19
1909	29.9	0.90
1910	44.0	0.40
1911	32.7	1.21
1912	22.4	1.92
1913	31.0	3.76
1914	31.1	1.52
1915	30.1	0.78
1916	26.2	3.09
1917	34.6	2.88
1918	37.1	3.58
1919	33.8	3.48
1920	35.2	3.57
1921	40.4	3.34
1922	35.4	3.69

Mean highest temperature	44.4
Mean lowest temperature	26.4
Mean temperature for month	35.4
Total precipitation for month	3.69

WEATHER.

Number days clear	8
Partly cloudy	10
Cloudy	13
With 0.01 inch or more of precipitation	15

SUNSHINE.

Number hours sunshine	186.0
Possible hours sunshine	370.5
Percentage of possible	50

BAROMETER—Mean, 30.07 inches; highest, 30.67 inches, on 1st; lowest, 29.13 inches, on 20th.

TEMPERATURE—Highest, 71°, on 25th; lowest, 14°, on 3d; greatest daily range, 34°, on 25th; least daily range, 3°, on 31st; normal temperature, 32.3°; departure, +3.2°; accumulated departure since January 1, +167°; average daily departure since January 1, +1.9°; highest in 37 years, 88°; lowest, 10°.

PRECIPITATION (in inches)—Total this month, 3.69; normal, 2.26; departure, +1.43; since January 1, −0.48; greatest amount in 24 hours, 0.97, on 30th; total snowfall, 11.3 in.

WIND—Prevailing direction, northwest; total movement, 5,877 miles; average hourly velocity, 7.9 miles; maximum velocity, 24 miles per hour from northwest on 20th.

DATES OF—Auroras, 0; hail, 0; sleet, 11, 18, 26, 30, 31; fog—dense, 0; thunderstorms, 6; halos—solar, 6, 9, 10, 13, 11, 17, 26; halos—lunar, 9, 12, 13, 14; frost—killing, —; heavy, —; light, —.

DEWEY A. SEELEY,
Meteorologist.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, APRIL, 1922.

Date.	Temperature.			Precipitation in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	42	25	34	0	Partly Cloudy	79
2	48	26	37	0	Cloudy	40
3	50	37	44	0.04	Cloudy	9
4	53	38	46	0	Partly Cloudy	78
5	57	34	46	T.	Cloudy	32
6	70	43	56	0	Partly Cloudy	45
7	74	49	62	....	Cloudy	39
8	67	45	56	T.	Partly Cloudy	43
9	73	54	64	0.12	Partly Cloudy	92
10	80	53	66	0.75	Partly Cloudy	77
11	59	35	47	1.19	Cloudy	28
12	41	32	36	0.03	Cloudy	5
13	51	31	41	0	Partly Cloudy	57
14	49	33	41	0.18	Cloudy	49
15	60	34	47	0	Clear	100
16	69	40	54	0	Clear	99
17	71	37	54	1.27	Cloudy	40
18	51	37	44	0	Clear	89
19	58	30	44	0.14	Partly Cloudy	60
20	45	27	36	0	Clear	85
21	49	31	40	0	Clear	100
22	52	30	41	0	Partly Cloudy	55
23	61	29	45	0	Clear	100
24	63	38	50	0	Cloudy	65
25	55	45	50	0.03	Cloudy	2
26	55	34	44	0	Cloudy	8
27	50	30	40	0	Partly Cloudy	62
28	54	28	41	0	Clear	100
29	65	31	48	0	Clear	100
30	67	34	50	0	Clear	100
31	....	....	....	....	....	....

Mean highest temperature	58.0
Mean lowest temperature	35.7
Mean temperature for month	46.8
Total precipitation for month	3.75

WEATHER.

Number days clear	9
Partly cloudy	10
Cloudy	11
With 0.01 inch or more of precipitation	9

SUNSHINE.

Number hours sunshine	247.9
Possible hours sunshine	402.5
Percentage of possible	62

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863	....	....
1864	45.9	3.80
1865	47.4	2.32
1866	48.9	1.40
1867	48.2	2.19
1868	43.7	1.83
1869	45.7	3.42
1870	50.4	2.02
1871	49.8	2.97
1872	47.4	1.26
1873	43.2	3.88
1874	36.9	1.67
1875	41.1	0.61
1876	44.2	2.08
1877	46.2	4.14
1878	50.6	3.76
1879	44.8	1.25
1880	45.9	7.06
1881	45.6	1.73
1882	44.7	1.88
1883	43.5	1.90
1884	43.7	1.95
1885	43.6	2.47
1886	50.2	1.99
1887	45.4	0.90
1888	44.0	1.15
1889	46.6	2.02
1890	47.2	3.20
1891	47.4	1.74
1892	44.5	2.04
1893	43.5	4.81
1894	48.4	2.76
1895	48.6	0.67
1896	52.6	2.77
1897	44.6	2.74
1898	43.6	2.12
1899	49.8	1.23
1900	47.4	2.00
1901	46.4	2.16
1902	44.6	1.70
1903	43.0	4.40
1904	39.4	0.50
1905	44.6	1.49
1906	46.6	2.43
1907	37.8	2.81
1908	44.6	2.15
1909	42.8	5.96
1910	49.2	2.48
1911	44.3	2.11
1912	45.6	3.12
1913	45.9	3.10
1914	44.7	2.90
1915	51.6	1.00
1916	45.7	1.91
1917	42.4	5.59
1918	42.4	1.97
1919	44.8	4.13
1920	39.9	3.25
1921	51.6	3.80
1922	46.8	3.75

BAROMETER—Mean, 30.04 inches; highest, 30.46 inches, on 28th; lowest, 29.06 inches, on 11th.

TEMPERATURE—Highest, 80°, on 10th; lowest, 25°, on 1st; greatest daily range, 34°, on 29th; least daily range, 9°, on 12th; normal temperature, 45.6°; departure, +1.2°; accumulated departure since January 1, +203°; average daily departure since January 1, +1.7°; highest in 37 years, 88°; lowest, 10°.

PRECIPITATION (in inches)—Total this month, 3.75; normal, 2.54; departure, +1.21; since January 1, +0.73; greatest amount in 24 hours, 1.93, on 10th and 11th; total snowfall, T. in.

WIND—Prevailing direction, west; total movement, 5,365 miles; average hourly velocity, 7.4 miles; maximum velocity, 32 miles per hour from southwest on 19th.

DATES OF—Auroras, 22; hail, 17; sleet, 0; fog—dense, 0; thunderstorms, 10, 17; halos—solar, 2, 4, 7, 8, 10, 11, 14, 19, 24, 26, 27; halos—lunar, 0; frost—killing, 20, 21, 22, 23, 27, 28, 29; heavy, 15, 30; light, 14, 16.

DEWEY A, SEELEY,
Meteorologist.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, MAY, 1922.

Date.	Temperature.			Precipitation in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	72	40	56	0	Clear	100
2	77	52	64	0	Partly Cloudy	73
3	62	56	59	0.46	Cloudy	6
4	70	51	60	T.	Cloudy	22
5	73	45	59	0	Partly Cloudy	92
6	72	51	62	0.02	Cloudy	55
7	70	44	57	0	Clear	100
8	70	40	55	0	Partly Cloudy	70
9	75	52	64	0.17	Cloudy	40
10	83	61	72	0.01	Clear	83
11	87	56	72	0	Clear	88
12	75	52	64	0.03	Partly Cloudy	53
13	73	49	61	0.06	Partly Cloudy	76
14	73	45	59	T.	Partly Cloudy	97
15	73	46	60	T.	Partly Cloudy	83
16	73	49	61	0.05	Partly Cloudy	76
17	68	54	61	0.23	Cloudy	15
18	66	55	60	0.54	Cloudy	18
19	61	54	58	0.80	Cloudy	3
20	74	53	64	T.	Cloudy	48
21	75	54	64	0	Clear	100
22	76	47	64	0	Clear	100
23	80	50	65	0	Partly Cloudy	97
24	83	58	70	0.95	Cloudy	42
25	78	61	70	0.02	Cloudy	40
26	80	49	64	0.05	Cloudy	43
27	74	46	60	0	Clear	100
28	77	46	62	0	Clear	100
29	80	46	63	0	Clear	100
30	83	54	68	0	Clear	96
31	81	52	66	T.	Partly Cloudy	69

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863	....	....
1864	60.2	2.87
1865	57.6	1.77
1866	55.0	3.48
1867	61.1	3.80
1868	59.1	2.80
1869	56.0	2.05
1870	64.3	1.16
1871	61.4	1.97
1872	58.5	3.72
1873	56.9	3.05
1874	59.6	1.77
1875	60.8	4.46
1876	58.0	4.13
1877	58.2	2.23
1878	54.6	3.44
1879	58.8	2.45
1880	64.3	5.59
1881	65.2	2.11
1882	52.7	4.04
1883	52.8	5.66
1884	56.9	3.95
1885	55.8	2.30
1886	58.1	2.67
1887	64.3	2.42
1888	53.7	3.66
1889	57.4	3.61
1890	53.7	4.98
1891	55.7	1.63
1892	54.5	5.92
1893	54.4	2.86
1894	56.9	4.83
1895	61.8	2.06
1896	66.5	3.14
1897	55.8	3.29
1898	56.5	2.15
1899	58.8	3.59
1900	58.8	4.17
1901	55.2	2.42
1902	58.4	4.92
1903	59.5	2.63
1904	57.4	2.40
1905	56.7	5.17
1906	56.6	3.05
1907	51.2	2.22
1908	59.6	5.59
1909	55.8	2.44
1910	51.5	4.13
1911	63.5	2.67
1912	57.6	6.57
1913	56.2	2.22
1914	58.6	4.66
1915	51.5	2.74
1916	56.6	5.13
1917	50.2	3.37
1918	61.1	2.89
1919	54.5	4.29
1920	55.1	1.43
1921	60.4	1.33
1922	62.6	3.39

Mean highest temperature	74.6
Mean lowest temperature	50.6
Mean temperature for month	62.6
Total precipitation for month	3.39

WEATHER.

Number days clear	10
Partly cloudy	10
Cloudy	11
With 0.01 inch or more of precipitation	13

SUNSHINE.

Number hours sunshine	306.3
Possible hours sunshine	454.7
Percentage of possible	69

BAROMETER—Mean, 29.96 inches; highest, 30.40 inches, on 1st; lowest. 29.16 inches, on 19th.

TEMPERATURE—Highest, 87°, on 11th; lowest, 40°, on 8th; greatest daily range, 34°, on 29th; least daily range, 6°, on 3d; normal temperature, 57.1°; departure, +5.5°; accumulated departure since January 1, +378°; average daily departure since January 1, +2.5°; highest in 37 years, 95°; lowest, 17°.

PRECIPITATION (in inches)—Total this month, 3.39; normal, 3.58; departure, −0.19; since January 1, +0.54; greatest amount in 24 hours, 1.32, on 18th and 19th; total snowfall, 0.0 in.

WIND—Prevailing direction, southeast; total movement, 3,497 miles; average hourly velocity, 4.7 miles; maximum velocity, 21 miles per hour from northwest on 7th.

DATES OF—Auroras, 0; hail, 0; sleet, 0; fog—dense, 4, 11; thunderstorms, 4, 6, 9, 12, 16, 17, 24, 25, 31; halos—solar, 1, 5. 8, 9, 14, 23, 24, 26; halos—lunar, 2; frost—killing, 0; heavy, 0; light, 0.

DEWEY A. SEELEY,
Meteorologist.

MONTHLY METEOROLOGICAL SUMMARY, LANSING, MICHIGAN, JUNE, 1922.

Date.	Temperature.			Precipitation in inches.	Character of day.	Percentage of possible sunshine.
	Highest.	Lowest.	Mean.			
1	72	44	58	0	Partly Cloudy	87
2	75	48	62	0	Partly Cloudy	100
3	76	52	64	0	Partly Cloudy	88
4	80	47	64	0	Clear	100
5	81	59	70	0.03	Partly Cloudy	47
6	84	58	71	0	Clear	90
7	88	60	74	0	Clear	99
8	86	66	76	0	Partly Cloudy	97
9	87	65	76	0.45	Partly Cloudy	78
10	82	63	72	0.56	Cloudy	49
11	77	59	68	0.08	Partly Cloudy	71
12	74	52	63	0	Clear	97
13	67	51	59	0.04	Cloudy	20
14	81	53	67	0	Partly Cloudy	100
15	84	56	70	0	Partly Cloudy	61
16	86	62	74	0.26	Partly Cloudy	44
17	72	61	66	0.02	Cloudy	23
18	72	59	66	0	Cloudy	53
19	79	53	66	0	Partly Cloudy	97
20	81	56	68	T.	Partly Cloudy	82
21	75	51	63	0	Partly Cloudy	62
22	79	49	64	0	Clear	100
23	87	49	68	0	Clear	95
24	91	62	76	0	Clear	95
25	68	48	58	0	Clear	86
26	73	47	60	0	Partly Cloudy	82
27	77	58	68	0.03	Cloudy	38
28	81	56	68	0	Partly Cloudy	71
29	83	60	72	0	Partly Cloudy	89
30	87	57	72	0.36	Partly Cloudy	43
31						

This month since 1863.		
Year.	Mean temperature.	Total precipitation.
1863		
1864	67.6	3.88
1865	70.8	3.55
1866	66.6	5.37
1867	71.6	2.83
1868	68.5	3.55
1869	64.4	4.40
1870	70.9	7.27
1871	68.2	2.93
1872	71.8	3.45
1873	70.6	2.96
1874	70.6	5.07
1875	66.6	1.84
1876	68.1	4.34
1877	65.9	3.53
1878	64.1	3.15
1879	66.0	2.87
1880	67.6	5.04
1881	64.3	4.37
1882	66.5	5.57
1883	65.9	11.35
1884	68.9	2.83
1885	64.7	6.01
1886	65.7	1.92
1887	68.5	2.47
1888	67.9	2.51
1889	62.8	3.42
1890	70.3	3.92
1891	67.4	2.55
1892	67.7	4.33
1893	66.6	4.85
1894	71.4	1.30
1895	71.4	1.01
1896	69.9	2.60
1897	64.2	2.57
1898	67.6	4.91
1899	68.2	1.15
1900	65.2	2.57
1901	68.0	3.57
1902	61.8	7.28
1903	62.0	6.28
1904	65.6	2.49
1905	66.2	7.47
1906	67.1	4.61
1907	65.0	2.37
1908	70.0	1.23
1909	66.7	2.86
1910	64.9	1.95
1911	68.0	3.77
1912	63.1	0.97
1913	67.6	1.01
1914	66.0	4.11
1915	61.0	3.96
1916	61.4	5.39
1917	62.4	4.54
1918	64.4	2.07
1919	71.9	3.18
1920	67.7	4.17
1921	70.6	3.24
1922	67.4	1.83

Mean highest temperature	79.5
Mean lowest temperature	55.4
Mean temperature for month	67.4
Total precipitation for month	1.83

WEATHER.

Number days clear	8
Partly cloudy	17
Cloudy	5
With 0.01 inch or more of precipitation	9

SUNSHINE.

Number hours sunshine	343.7
Possible hours sunshine	459.4
Percentage of possible	75

BAROMETER—Mean, 29.98 inches; highest, 30.25 inches, on 25th; lowest, 29.53 inches, on 11th.

TEMPERATURE—Highest, 91°, on 24th; lowest, 44°, on 1st; greatest daily range, 38°, on 23d; least daily range, 11°, on 17th; normal temperature, 67.2°; departure, +0.2°; accumulated departure since January 1, +386°; average daily departure since January 1, +2.1°; highest in 37 years, 99°; lowest, 34°.

PRECIPITATION (in inches)—Total this month, 1.83; normal, 3.40; departure, −1.57; since January 1, −1.03; greatest amount in 24 hours, 0.82, on 9th and 10th; total snowfall, 0.0 in.

WIND—Prevailing direction, southwest; total movement, 3,031 miles; average hourly velocity, 4.2 miles; maximum velocity, 20 miles per hour from south on 30th.

DATES OF—Auro, 0; hail, 0; sleet, 0; fog—dense, 0; thunderstorms, 5, 9, 10, 16, 27, 30; halos—solar, 2, 3, 26; halos—lunar, 1; frost—killing, 0; heavy, 0; light. 0.

DEWEY A. SEELEY,
Meteorologist.

REPORT OF THE DEPARTMENT OF HISTORY AND POLITICAL SCIENCE.

President David Friday,
East Lansing, Michigan.
Dear Sir:

The Department of History and Political Science submits the following report for the year 1921-22.

The department staff has been busily occupied in teaching the courses offered in the various divisions. Two things stand out with some prominence in the year's experience. One is the enlarged enrollment in our classes. This is due partly to a more general interest in the subject matter on the part of our students, and partly to the addition of one or more new courses for the Applied Science Division.

Another feature of our work is the addition to the curriculum of courses in Industrial History. The opportunity to add this was very welcome since the desirability of such courses had been apparent for a number of years. We hope to make this work worth while as time is found to develop courses of this nature.

We cannot forego the opportunity to express our conviction that students in the technical divisons should find opportunity to pursue courses in History and Political Science in one or more terms of the earlier years of the courses. The value of this subject matter to college students is increasingly recognized today. Somewhere in the early part of his college career, a survey of the great historical movements in human affairs ought to be given consideration.

In closing, I express my appreciation of the splendid efficiency of my associate in the work of the department, in the person of Mrs. Mary Hendrick.

Very truly yours,
E. H. RYDER,
Professor of History and Political Science.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF MUSIC.

President David Friday,
Michigan Agricultural College.
Dear Sir:

The report of the Department of Music for the year ending June 30, 1922, is as follows.

	Number of students enrolled		
	Fall	Winter	Spring
Piano	37	48	24
Voice	44	48	32
Violin	16	21	14
Harmony	9	6	1
Band Inst.	23	23	14
Total	129	146	85

These students received one lesson a week, with five hours practice. Recitals were given from time to time by those who were qualified. Music was furnished for all occasions both on and off the campus.

The Men's Glee Club assisted when called upon. The orchestra was a new feature this year and was made possible only by the untiring work of Miss Delia Bemis, Instructor in Violin. We had the best band in the history of the College, and prospects are for a much larger enrollment in all departments next fall.

Our needs are many, and we hope that in the near future many of them will be met, particularly a larger building and some new equipment.

Respectfully submitted,
J. S. TAYLOR,
Director of Music.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF PHYSICS.

President David Friday,
Michigan Agricultural College.
Dear Sir:

My annual report of the Physics Department for the school year ending June 30, 1922, is herewith submitted.

The department personnel consisted of the following:

Charles W. Chapman, Professor of Physics.
William E. Laycock, Associate Professor of Physics.
Oren L. Snow, Associate Professor of Physics.
(Appointed, Jan. 1, 1922.)
Edwin Morrison, Assistant Professor of Physics.
Wilbur H. Thies, Instructor in Physics.
S. Elizabeth Morrison, Laboratory Assistant and Clerk.
Ralph M. Harford, Staff Photographer.
Wallace W. Tappan, Caretaker.

The only addition to the teaching staff was Associate Professor Oren L. Snow who returned to the Physics Department, Jan. 1, 1922, after having been associated with the United Engine Company of Lansing, Michigan, since he resigned, Sept. 1, 1918, to accept a more lucrative position with that company. We welcome his return, feeling that the loss sustained by us in his going has been more than made up by the invaluable experience he has brought back to us. Mr. Snow was engaged to fill the vacancy caused by the resignation of Mr. E. B. Butler, Sept. 1, 1921.

Although short one instructor during the fall term, all scheduled work of that term was given with one exception,—that is, Physics 4a was omitted. This was accomplished only by crowding the work, using student assistants for quiz and maintaining evening laboratory classes.

The tabulation below furnishes complete information as to the subjects in physics taught each term, the number of hours per week devoted to lecture, quiz and laboratory work and the enrollment in each subject, per term.

SUMMER TERM, 1921.

Subject.	Required of	Course.	Elective or Optional for	No. of Hours Per Week.			Enrollment
				Lect.	Quiz.	Lab.	
Physics 1d	Sophomores	Agr'l and For		4	4	4	13
Physics 1e	Sophomores	Agr'l and For		4	4	4	9
Physics 3d	Sophomores	H. E.		4	4	4	8
Physics 4b			Agr'ls, For's and H. E.'s	4	4	4	15
Prep. Phys. 1a				4	4	4	9
Prep. Phys. 1b				4	4	4	36
Total							90

FALL TERM, 1921.

Physics 1d	Sophomores	Agr'l and For	Applied Science	2	2	2	124
Physics 2d	Sophomores	Engineering		2	2	2	104
Physics 6d			Applied Science	2	2	2	16
Prep. Phys. 2a	Entrance	Engineering		2	3	2	4
Prep. Phys. 2b	Entrance	Engineering		2	3	2	4
Total							252

WINTER TERM, 1921.

Physics 1e	Sophomores	Agr'l and For	Applied Science	2	2	2	121
Physics 2f	Sophomores	Engineering		2	2	2	107
Physics 6e			Applied Science	2	2	2	17
Short Course (16 weeks, last 8 weeks—Second Year)							11
Vocational Guidance School							80
Total							336

SPRING TERM, 1922.

Subject.	Required of	Course.	Elective or Optional for	No. of Hours Per Week.			Enrollment
				Lect.	Quiz.	Lab.	
Physics 2e	Sophomores	Engineering		2	2	2	106
Physics 6e			Applied Science	2	2	2	18
Physics 3	Freshmen Sophomores	Technical H. E. Technical, H. E.		2	1	4	120
Physics 5	Freshmen	Veterinary		2	1	4	12
Vocational Guidance School							35
Total							391
Total number of students enrolled in all subjects in physics							1,069

(NOTE: By request of the H. E. Div., Physics 3 was given to Sophomore Technicals, instead of Sophomore Generals as scheduled, to assist in adjustments to the New Home Economics Course.)

Physics 2f Magnetism and Electricity, was given during the winter term instead of Physics 2e, Heat, Sound and Light, as scheduled, interchanges of subjects having been permitted by faculty action. Hereafter Physics 2f will precede Physics 2e.

Physics 3e was not given spring term. Those back in the subject were classified in Physics 3 and credit substituted.

New subjects in Physics given for the first time were:

(a) Physics 3 (Required of Technical Freshmen in the Home Economics Course and Sophomore Generals in the Home Economics Course).
(b) Physics 6d, 6e and 6f (Elective for Applied Science Students).

Subjects omitted by faculty action, because of insufficient room and lack of instructional force, were as follows:

(a) Physics 4a (Elec. for Agr'l, For. and Science Courses).
(b) Physics 4b (Elec. for Agr'l, For., H. E. and Science Courses).
(c) Physics 4c (Elec. for Agr'l and For. Courses).

Since Physics has now become a major subject in the Applied Science Course, the need for another instructor and adequate lecture, laboratory and quiz room in which to satisfactorily handle our work, has become imperative. In fact it will be impossible to give our complete schedule of work, until these are provided. Physics 6g, 6h and 6i, also Physics 6k, 6m and 6n, (Electives for seniors in Science Course), cannot be offered until then.

Respectfully submitted,
CHAS. W. CHAPMAN,
Professor of Physics.

East Lansing, Mich., June 30, 1922.

REPORT OF THE DEPARTMENT OF PHYSICAL TRAINING.

President David Friday,
Michigan Agricultural College.
Dear President Friday:

I beg to submit the following report of the work in the Department of Physical Training during the past year:

Physical training was not required of all students during the past year, but the large majority of them engaged in some recreative activity. This is shown by the fact that the gymnasium was in full use from 8 o'clock in the morning to 9 o'clock in the evening, 6 days a week.

First year men received training in army physical drill, calisthenics, mass and recreative games. In addition they were given lectures in health education and public hygiene. The second year men were given their choice of the aforementioned activities or engaging in Varsity athletics, swimming, fencing, apparatus drill, boxing, or wrestling.

The upper classmen took exercise in intramural athletics. Schedules were arranged for both interclass and intersociety competition in basketball, track, indoor baseball, outdoor baseball, swimming and tennis. In addition, Varsity teams were maintained in football, basketball, baseball and track. Our Varsity teams competed with the leading teams of the Western Conference and the Middle West. The football team made trips to the University of Michigan, Marquette University at Milwaukee, Notre Dame University at South Bend, and Butler College at Indianapolis; the basketball team to the University of Michigan, Ohio Wesleyan University at Delaware, Oberlin College and Creighton University at Omaha; the baseball team to the University of Michigan, Notre Dame University, Armour Institute at Chicago, Oberlin College and Bethany College in West Virginia; the track team entered the De Paul Meet at Chicago and the Drake Relays in Iowa. The track team won distinction at the Drake Relays by winning the two mile college championship relay and the 440 yard hurdle race. Minor sports, a new phase of work introduced in our department included, hockey, swimming, wrestling, and tennis. Intercollegiate competition was also scheduled in these sports.

Physical training for women is required of freshmen and sophomores, three hours a week, and elective for upperclass women. A physical and medical examination is required of all new students. A general program of calisthenics, corrective work, swimming, which is a required subject, is given to the freshmen. Sports represented are hockey, soccer, basketball, baseball, archery, rifle and tennis. Tennis and rifle are Varsity sports. All others are given as interclass sports. Upperclass women are given a complete two year course in physical education, with the view that they will be able to instruct in the same.

The gymnasium is now splendidly equipped. The great need, however, is the addition of an outdoor athletic plant. Our present wooden stands are nearly worn out and entirely inadequate. The field is too small and the annual spring floods make it uncertain and unsatisfactory.

I respectfully call your attention to the fact that the department touches the life of every student in the Institution. This contact is a very vital one, playing an important part in the well-rounded man and woman. The teaching force during the year has been as follows:

C. L. Brewer, Director.
L. L. Frimodig.
A. M. Barron.
J. H. Devers.
J. Heppinstall.
Helen Grimes.
Jessie MacCornack.
Gertrude Loudenback.

Respectfully submitted,
L. L. FRIMODIG,
Assistant Director.

East Lansing, Michigan, June 30, 1922.

REPORT OF SUMMER SESSION.

President David Friday,
East Lansing, Michigan.
Dear Sir:

I desire to submit a brief report of the summer session for the season 1922. This session opened on Monday, June 26th, immediately following the closing of the spring term and continued for six weeks ending on August 4th.

The curriculum of this session was similar to that of our preceding summer sessions. An endeavor was made to offer courses suited to the needs of the various groups interested in summer work, including those who had failed during the year and used the summer session to adjust themselves in their college courses. This demand arises especially in the elementary work of Chemistry, English and Mathematics.

A liberal number of advanced courses in the Divisions of Agriculture and Home Economics was offered to satisfy the needs of students utilizing the summer session to either shorten the stay in college or to supplement their courses selected for the regular terms. The large number of our students who are making use of this session for such reasons is increasing and is one of the most substantial reasons for maintaining a summer session.

A third group to whom we endeavor to minister each year with not all together satisfactory results in numbers is the students from outside our student body. The quality of this contingent is high grade. Many come from the ranks of the teaching profession and are invariably very earnest, capable students. These include superintendents, principals and instructors of our high schools, who come to us to get the Agriculture and other sciences offered by this College. Much more attractive terms in the adjustment of credit submitted from other institutions recently established ought to add to the numbers of this group.

Special efforts were put forth this summer for a new group of students. As a result of the consolidation movement in our school system, the department of Public Instruction found a shortage of teachers of Agriculture to man these schools. At the suggestion of State Superintendent Johnson, the College presented the technical subject matter of the departments of Animal Husbandry, Dairy Husbandry and Farm Crops to some fourteen men picked by the Department of Public Instruction for this purpose. These men continued in residence through nine weeks or until the close of their vacations, covering some twenty-four credits of work. This undertaking necessitated a large amount of labor in selecting and rearranging the material of the courses in the departments by the instructors. The fact that the group stayed by and went away with words of satisfaction speaks well for the success of the men who did the teaching. The plan of last summer contemplated, if successful, the continuance of the plan during another summer in order to cover the remainder of the technical field. I recommend that this be done.

Still another group consisted of teachers of Home Economics in the high schools of the State who were invited to attend the session for advanced work presented by special teachers under the auspices of the State Board in charge of vocational education. Special instructors were provided by the above Board including Miss Ruth Cowan of University of Illinois, Miss Ruth Wilson of Iowa College, Ames, Iowa, Miss Margaret Stewart of Chicago, and K. G. Smith, State Supervisor of industrial education in Michigan. The purpose of this work in household science and household art was to strengthen the resources of teachers in the high schools of the State in the field of Household Economics. So profitable and satisfactory was this effort that we hope to continue such work in the session of 1923.

Finally the College arranged special courses in drawing and manual training continuing for a two weeks' period for the teachers of Agriculture in the high schools. This was the third successive year that work of this kind had been given. The effort has seemed very much worth while each year.

The foregoing paragraphs contain a brief summary of the work of the session. It is to be noted that our efforts have been confined to the needs that can be met by M. A. C. to the best advantage. We have purposely avoided any effort that might seem to mean duplicating other summer schools. Response to our efforts have seemed to justify this policy.

E. H. RYDER,
Director of Summer School.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DEPARTMENT OF ZOOLOGY AND PHYSIOLOGY.

To the President,
Michigan Agricultural College.
Sir:

I have the honor to submit the following report of the Department of Zoology and Physiology for the year ending June 30, 1922.

The resignation of Assistant Professor Verne E. LeRoy during the summer of 1921 left a vacancy in the staff which has not been filled. Dr. H. E. Johnson and Dr. O. A. Taylor, both of the Veterinary Division, were assigned temporarily for work in the physiological laboratory and have continued to give more or less help through the year. With these exceptions there has been no change in the personnel of the department.

The following data will give some idea of the kind and amount of class work each term:

Fall term.	Two classes in zoology	82 students	
	Two classes in physiology ...	156 students	
	Four classes in geology	84 students	322
Winter term.	Three classes in zoology	59 students	
	Three classes in physiology ...	100 students	
	Three classes in geology	69 students	228
Spring term.	Three classes in zoology	57 students	
	Two classes in physiology ...	29 students	
	Two classes in geology	42 students	128
Summer School (1921).			
	Two classes zoology	13 students	13
	Total number of students		691

Summary: Total number of classes during the year, 26; elective, 11; optional, 1; required, 14. Number of students taking electives, 138; optional, 26; required, 527. Average number in required classes, 37.6; in elective classes, 12.5.

The marked inequality in the number of students handled in the different terms is largely due to the change in the Home Economics curriculum which required the repetition of some of the physiology previously dropped from that course and now restored. Probably such a congestion will not occur again.

Eighteen students elected Applied Science work in zoology in the fall term and thirteen of these carried it through the year.

It seems worth while to note the fact that although the department is now offering twice as many courses as five years ago, there has been little change in current expenses and no increase in the teaching force. Naturally this cannot continue indefinitely, especially if the Applied Science course developes as expected.

Extension work, as always, has occupied a considerable portion of department time and thought. The demands come mainly in two ways,—as requests for addresses, lectures or talks, particularly illustrated talks, and in the form of questions as to the names, habits and value of a great variety of animals, especially for such as are known to be pests or thought likely to become so. Requests for lectures can be complied with only in a few cases, partly because of the expense but more often through our inability to take an instructor from his regular class work in order to make the necessary trip. However, Professor A. C. Conger and the head of the department have made a number of such trips during the past year. besides giving short talks before local clubs and schools which could be reached with little loss of time. Almost every talk of this kind, however, results in several requests from other sources, most of which unfortunately must be refused. A constant stream of inquiries by mail is met by the use of circular letters so far as possible, but hundreds of questions need special replies and this correspondence grows more and more burdensome every year. Bits of mica, pyrite, calcite, quartz and other common minerals with shining particles are sent for "analysis" with the idea that they may contain gold, silver or gems, or have some high economic value in other ways. Many of these are referred to the State Geologist, Department of Conservation, Lansing, where they should have been sent originally, together with questions about oil, coal, gas, peat, iron ore, brick-clays, building stone, etc. In other cases, where there can be no question, a direct answer is made, with the advice to send similar requests in the future to the above address.

The matter of fur-farming is a prolific source of correspondence, the interest in Michigan growing steadily if not always healthily. This industry promises good returns to those only who can spend both time and money freely, and it is well-nigh certain that a large proportion of those who go into it hurriedly will get rich only in experience. Much of the information asked from us does not as yet exist, and many of the problems are of such a nature that only one who has had some scientific training is capable of using to advantage the suggestions made. Perhaps the best general advice which we can offer is to make the first ventures on a small scale, only increasing the business later if experience warrants it.

The General Museum, used constantly in connection with classwork, but open daily to the public, has changed little during the past season. Numerous gifts of single specimens have been received from students and alumni, and some local material has been collected and put on exhibition by the department members. Perhaps the most noteworthy gift is a collection of ores, principally of copper and silver, from the famous Upper Peninsula copper mines, presented by Charles M. Turner of Lansing. The needs of the College Museum have been so often mentioned in these reports that little more need be said now, but we cannot refrain from expressing once more the hope that its valuable collections may be speedily housed in some suitable place which is at least moderately fire-proof.

Respectfully submitted,
WALTER B. BARROWS,
Professor of Zoology and Physiology and Curator
of the General Museum.

East Lansing, Michigan, June 30, 1922.

REPORT OF SECRETARY AND TREASURER.

The following show the receipts and disbursements of the Experiment Station for the year ending June 30, 1922.

SCHEDULE K-1.

		Dr.	Cr.
July 1, 1921.	To balance	....	....
Aug. 11, 1921.	received from U. S. Treasury	$7,500 00	
Oct. 19, 1921.	received from U. S. Treasury	7,500 00	
Jan. 18, 1922.	received from U. S. Treasury	7,500 00	
Apr. 20, 1922.	received from U. S. Treasury	7,500 00	
June 30, 1922.	State Treasurer, one-fifth mill fund	90,000 00	
	license fees, commercial feeding stuffs	40 00	
	Graham Horticulture Experiment Station	1,032 31	
	Upper Peninsula Experiment Station	4,693 54	
	South Haven Experiment Station	727 99	
	By disbursements as per vouchers filed in office of the State Auditor General	....	$234,458 69
	Balance overdrawn	103,376 23	
Total		$234,458 69	$234,458 69

Sixteen thousand special bulletins No. 107; five thousand special bulletins No. 108; fifty thousand special bulletins No. 109; twelve thousand special bulletins No. 110; five thousand special bulletins No. 111; five thousand special bulletins No. 112; forty-five thousand special bulletins No. 113; twenty-five thousand special bulletins No. 114; twenty thousand special bulletins No. 115; twenty thousand special bulletins No. 116; four thousand technical bulletins No. 52; four thousand technical bulletins No. 53; four thousand technical bulletins No. 54; four thousand technical bulletins No. 55; forty-five thousand quarterly bulletins, Vol. 4, No. 1; forty-five thousand quarterly bulletins, Vol. 4, No. 2; forty-five thousand quarterly bulletins, Vol. 4, No. 3; forty-five thousand quarterly bulletins, Vol. 4, No. 1, have been issued by the Experiment Station during the fiscal year.

DISBURSEMENTS ON ACCOUNT OF U. S. APPROPRIATIONS—SCHEDULE K-2.

	Hatch Fund.	Adams Fund.
Salaries:		
Director and other administrative officers	$1,743 80	....
Scientific staff	2,950 40	$824 70
Assistants to scientific staff	8,253 55	13,729 50
Labor:		
Annual and monthly employees	1,443 11	200 00
Hourly employees	609 14	245 80
Total	$15,000 00	$15,000 00

DISBURSEMENTS OF EXPERIMENT STATION MONEYS—OTHER THAN RECEIVED FROM U. S. TREASURER—SCHEDULE K-3.

Salaries	$110,572 57
Labor	37,139 21
Publications	13,011 45
Postage and stationery	1,602 40
Freight and express	1,172 96
Heat, light, water and power	694 84
Chemicals and laboratory supplies	2,786 19
Seeds, plants and sundry supplies	5,638 78
Fertilizers	1,532 69
Feeding stuffs	4,492 68
Library	671 92
Tools, machinery and appliances	3,062 15
Furniture and fixtures	1,031 51
Scientific apparatus and specimens	1,266 52
Live stock	1,841 60
Traveling expenses	11,983 94
Contingent expenses	81 80
Buildings and lands	5,875 48
Total	$204,458 69

THIRTY-THIRD ANNUAL REPORT

OF THE

EXPERIMENT STATION

OF THE

Michigan Agricultural College

UNDER THE HATCH AND ADAMS ACTS

FOR THE

YEAR ENDING JUNE 30, 1920

For members and organization of the State Board of Agriculture in charge of the Station and list of officers, see pages 5 and 14 of this volume.

REPORT OF THE DIRECTOR OF EXPERIMENT STATION.

To President David Friday:

I am submitting herewith the individual reports of the various sections of the Experiment Station. As these reports are complete it is unnecessary for this office to enter into detail. We desire to express an appreciation of the entire staff for their persistent pursuance of research problems during the year, resulting in the accomplishment of results of much direct value to the farmer. The services rendered to the office of the director as well as to the various sections of the Station by Mr. E. B. Hill, Assistant to the Director, have resulted in a much greater efficiency than heretofore. Project forms and Reports of Progress prepared by Mr. Hill have placed the records of this office in a much more satisfactory condition.

Marked progress was made during the year at the Upper Peninsula Station at Chatham now comprising 780 acres. About 150 additional acres of cut over land has been cleared and is being prepared for cultivation, crops production, live stock, soil fertility, and land clearing methods and costs have been given special stress. This sub-station serves a constituency comprising nearly one-third of the total land area of the State. During this year a bulletin entitled "The Agriculture of the Upper Peninsula" was published, reviewing the experimental work of the sub-station and presenting much information of a general character of service to all interested in the agriculture of this region.

Before the opening of the present crop year a 40 acre tract of land near Mancelona was deeded over to the State Board of Agriculture to be used for experimental purposes. The initial work of establishing tests relating especially to soil fertility problems and potato production was begun this season. This sub-station consists of soil types representing a large area of the State and will be useful in investigating problems pertaining thereto.

Substantial support was given the Station during the year through supplementary state aid granted by the State Board of Agriculture from current funds of the College. There are now over one hundred and eighty investigational projects in progress. The following statement includes the funds disbursed during the year indicating their source:

Hatch	$ 15,000 00
Adams	15,000 00
State	204,458 69
Total	$234,458 69
Upper Peninsula Station	25,091 64
Graham Fruit Station	8,951 20
South Haven	4,867 74

The three sub-station funds are included in the State appropriation given above.

LIST OF BULLETINS

Regular:
- 291—Fertilizer Analyses.
- 292—Commercial Feeding Stuffs.

Special:
- 107—Diseases of Bees in Michigan.
- 108—The Robust Bean.
- 109—Dependable Michigan Crop Varieties.
- 110—Special Report of the Upper Peninsula Experiment Station.
- 111—Studies in City Milk Distribution.
- 112—An Experiment in Improving the Milk Supply of a City Milk Plant.
- 113—Sweet Clover.
- 114—Spray and Practice Outline.
- 115—Dusting and Spraying Experiments of 1920 and 1921.
- 116—The Agriculture of the Upper Peninsula.

Technical:
- 52—The Colorimetric Hyrdogen Ion Determination as a Means of Studying Biological Changes in Dairy Products.
- 53—A Phoma Root Rot of Celery.
- 54—Studies in the Diseases of the Productive Organs of Cattle.
- 55—The Comparative Pathogenicity of Several Strains of Bacterium Abortus (Bang).
- 56—Leafhopper Injury to Potatoes.

Respectfully submitted,
R. S. SHAW,
Director of Experiment Station.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE SECTION OF ANIMAL HUSBANDRY.

Director R. S. Shaw,
College.
Dear Sir:

I have the honor to submit the following report of the experimental work conducted by the Animal Husbandry Section during the year ending June 30, 1922.

The work started with stover silage in 1920 is being continued. The steers in Lot 1 were fed normal corn silage; Lot 2, stover silage; and Lot 3, stover silage with the corn which was removed when the stover was ensiloed returned to the ration. The results of the two years' work are as follows:

	Daily gain.		Cost per cwt. gain.		Profit per lot.	
	1920-21.	1921-22.	1920-21.	1921-22.	1920-21.	1921-22.
Lot 1	1.94 lb.	2.39 lb.	$8 81	$7 88	*—$15 02	**+$43.80
Lot 2	1.42 lb.	1.72 lb.	10 01	8 38	—21 15	+34 96
Lot 3	1.58 lb.	2.03 lb.	10 01	8 23	—24 00	+42 93

*—Loss. **+Profit.

This test will be repeated during the winter of 1922-23, after which a final report will be made.

Five trials have been conducted with seven lots of pigs in each trial to determine the relative efficiency of the different grains commonly grown in Michigan.

Rations used were as follows, all feeds being self-fed—free-choice method.

Lot 1—Corn, Barley, Rye and Tankage.
Lot 2—Rye and Tankage.
Lot 3—Barley and Tankage.
Lot 4—Corn and Tankage.
Lot 5—Barley, Rye and Tankage.
Lot 6—Barley, Middlings and Tankage.
Lot 7—Rye, Middlings and Tankage.

	Lot 1. Corn, Rye, Barley Tankage.	Lot 2. Rye Tankage.	Lot 3. Barley Tankage.	Lot 4. Corn Tankage.	Lot 5. Barley Rye Tankage.	Lot 6. Barley Midds. Tankage.	Lot 7. Rye Midds. Tankage.
Number of pigs fed	30	30	30	30	32	32	32
Average daily gain	1.391	1.151	1.301	1.472	1.21	1.17	1.12
Feeds consumed per 100 pounds of gain:							
Corn (shelled)	239	....	....	395	....	....	....
Barley (ground)	53.5	....	444	....	257	269	....
Rye (ground)	139	414	....	....	178	....	195
Middlings	....	....	....	....	....	157.7	226
Tankage	30.5	42	28	40	32	26.6	25
Total	462.0	456	472	435	467	453.3	447

The average initial weights of the pigs in the different tests varied from 59 lbs. to 146 lbs. but in each test the initial weight of the pigs in the different lots was approximately the same. The final weights of the hogs in the different tests varied from an average of 155 pounds to 261 pounds.

Returns received for home-grown grains fed in above trials after paying for tankage @ $60.00 per ton and middlings @ $30.00 per ton. Hogs selling at from $6.00 to $10.00 per cwt.

Lot.	Feeds.	$6.00 Hogs.	$7.00 Hogs.	$8.00 Hogs.	$9.00 Hogs.	$10.00 Hogs.
1	Corn, rye, barley per 100 lbs	$1 18	$1 41	$1 64	$1 87	$2 10
	Supplemented by tankage.					
2	Rye per 100 lbs	1 14	1 38	1 63	1 87	2 11
	Rye per bushel	64	78	91	1 05	1 18
	Supplemented by tankage.					
3	Barley per 100 lbs	1 16	1 39	1 61	1 84	2 06
	Barley per bushel	56	66	77	88	99
	Supplemented by tankage.					
4	Corn per 100 lbs	1 21	1 47	1 72	1 97	2 23
	Corn per bushel	68	82	96	1 10	1 25
	Supplemented by tankage.					
5	Rye, barley per 100 lbs	1 16	1 39	1 62	1 85	2 08
	Supplemented by tankage.					
6	Barley per 100 lbs	1 05	1 43	1 80	2 05	2 54
	Barley per bushel	51	68	86	98	1 22
	Supplemented by middlings and tankage.					
7	Rye per 100 lbs	93	1 44	1 95	2 46	2 98
	Rye per bushel	52	81	1 09	1 38	1 67
	Supplemented by middlings and tankage.					

No attempt is made to give the per bushel value of the grains consumed by Lots 1 and 5, as two or more home-grown grains were used in the rations fed these two Lots.

In Lots 6 and 7, it was unprofitable to feed middlings at $30.00 per ton with barley and tankage or rye and tankage when hogs sold below $7.00 per hundred pounds.

In Lots 6 and 7 the value of rye is given very high with hogs at $9.00 and $10.00 per hundred pounds and middlings at $30.00 per ton owing to the small amount of rye consumed.

While the free-choice method of feeding has been advocated for several years, the results of the above trials show that in the majority of the trials the pigs failed to properly balance their ration if we accept the standard in general use as correct. There was also a wider variation in the nutritive ratio used by the pigs in different periods of the same trials than seems desirable.

As a result a second series of trials with the above feeds is being planned with the feeds being mixed according to accepted standards and then placed in the self-feeder.

Respectfully submitted,
GEO. A. BROWN,
Animal Husbandman.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE SECTION OF ANIMAL PATHOLOGY.

Director R. S. Shaw,
College.
Dear Sir:

I herewith submit the report of the Animal Pathologist for the year ending June 30th, 1922.

Work on the diseases of the reproductive organs of cattle has been continued during the past year. A report of this work has been published as Technical Bulletin No. 54 under date of November 1921.

In December 1921 we had the privilege of autopsying six head of cattle that were killed out of a herd in which abortion and sterility has been a serious problem for several years. These cattle were killed on account of having reacted to the tuberculin tests. Two were pregnant and material was obtained from these for work on the evolution of the uterus which will be referred to below. One had calved ten days preceding slaughter and furnished valuable material for our study on the involution of the uterus. Two were open (sterile) and one had a dead fetus in the uterus. At this point we wish to discuss the latter three cases.

Cow No. 6308 was examined July 3, 1920 because of failure to conceive. She was approximately two years old at that time and had been served several times but failed to conceive. At the time of examination a portion of the hymen remained as a narrow band reaching from the dorsal to the ventral wall of the vagina. This was removed. There was a corpus luteum in the right ovary which could not be removed. No other alterations were observed. She was bred July 17th and 20th, 1920. November 6th, 1920, examination was made and found not pregnant. She was bred several times during the following winter and ran loose in pasture with bull from July 19th to September 13th, 1921. On October 29th, 1921, examination revealed presumptive evidence of pregnancy. November 19th, 1921, another examination for pregnancy was made. Presumptive evidence was obtained but enlargement of uterine horn was not as well marked as should be expected. The animal was slaughtered December 13th, 1921.

Macroscopic examination: The left uterine horn is about twice the size of the normal non-pregnant horn of a cow that has had one or more calves. In this horn is a dead fetus about six centimeters in length. The fetal membranes are shrunken, appear as a fattened band about 35 centimeters in length by six millimeters wide. The mucosa of left horn is moist and glistening, is a veal flesh color and it is not possible with the naked eye to distinguish the regions of the cotyledons. The right horn is smaller than the left and contains about ten cc. of a creamy yellow exudate. The mucosa shows no cotyledons and is similar in appearance to that of the left.

There is no enlargement of either oviduct. The left ovary has a full size corpus luteum and two cysts ten and fifteen millimeters in diameter respectively.

Streptococcus viridans was isolated from the uterus.

Histological examination: In the mucosa of the left horn there is considerable edema of the stroma. The uterine glands are dilated as in pregnancy. Occasionally the epithelium lining the pits shows slight granular degeneration. In forty-seven sections studied from six different portions of the left horn no cotyledons are observed. At one point there are observed a few arterioles grouped in the sub epithelial tissue, suggesting a cotyledon but here there is an absence of the characteristic tissue of the cotyledon.

Whether the apparent sterility and death of the fetus was due to the absence of maternal cotyledons cannot be answered at this time. The placental epithelium is phagocytic and it seems that attachment might occur at any point of the mucosa. On the other hand the gland mucosa does not possess the rich vascular supply near the surface that the cotyledon possesses and it may be that the chorionic villi do not find an adequate blood supply when attachment is made to the gland mucosa. Possibly the rich blood supply of the cotyledon accounts for the positive chemotaxis of the cotyledon for the chorionic villus.

In the mucosa of the right horn there are no marked alterations.

In a few places the nuclei of the epithelium are faintly stained and in a few other places slight granular degeneration of the epithelium is seen. The glandular epithelium of a few of the glands show slight mucoid changes.

There are no alterations of the oviducts other than near the fundus it appears that there may be an excessive number of lymphocytes entangled within the cilia of the epithelium.

Cow No. 6312—was an aged cow (exact age and past breeding record not definitely known). Her last calf was February 19, 1920. She had been persistently bred since then but failed to conceive. During the last half of the year 1921 she was bred as follows: May 27th, June 17th, August 9th, September 6th and October 2nd. Cow was slaughtered December 13th, 1921.

Macroscopic examination: The ventral portion of the first fold of cervical mucosa is considerably hypertrophied and shows numerous cysts varying in size from one-half to three millimeters in diameter. There is a tenacious mucus in cervical canal. The uterine horns are not enlarged. The uterine mucosa is not uniform in color. The region of the cotyledon is a brownish red color with numerous small grayish yellow focci. The gland mucosa is a grayish brown color. Both oviducts are about twice their normal size. There are no fibrous constrictions in the oviducts.

The left ovary contains a cyst about ten millimeters in diameter. No cultures were obtained from this case.

Histological examination: The posterior cervical mucosa shows numerous cysts varying from single cysts seventy-five microns in diameter to multilocular cysts two to three millimeters in diameter. The cysts are lined with flattened cells resembling endothelial cells, and contain a deeply stained (basic) granular material.

In the uterine mucosa there is marked lymphocytic infiltration of the stroma with marked peri-glandular fibrosis. The appearance of the mucosa is that of a chronic hypertrophic endometritis.

There are no marked alterations of the posterior portions of the oviducts except a slight lymphocytic infiltration of the stroma with here and there a peri-vascular small round cell infiltration. In the middle portion of the oviducts, and to a less extent in the anterior portion there is well marked mucoid degeneration of the epithelium and lymphocytic infiltration of the stroma. There is also a marked cellular and granular exudate in the lumen. The appearance of the mucosa is that of an acute catarrhal salpingitis.

Cow No. 6315 was a cow eight or nine years old. She had been treated several times during the summer by attending veterinarian for failure to conceive. At autopsy the only alterations apparent were hypertrophy of the right lateral portion of the first fold of cervical mucosa and the right ovary contained a cyst about the size of a hen egg.

Histological Examination failed to demonstrate any alterations of the uterine mucosa or of the tubes.

Considerable time has been devoted to a study of evolution and involution of the cow's uterus during and subsequent to pregnancy. As far as the writer knows no American investigator has devoted any time to this problem. A little work has been done by some of the European investigators but their results are not generally available to the profession in this country. There are two principal reasons why the writer has devoted a part of his time to this problem. First because a knowledge of the physiological processes of the pregnant and involuting uterus is of considerable scientific interest. Second, it is the writer's opinion that a knowledge of these processes will explain many of the unsolved problems pertaining to infections of the parturient and post parturient uterus and infections of the fetus.

An abundance of material is available for the study of evolution of the uterus but the material for study of involution is limited. However, some material is available and we are recording some very interesting observations. We do not feel that the work on this problem is sufficiently advanced to warrant publication of the observations already made but it is hoped that the problem may be continued.

Another problem studied during the past year is a study of the bacteriology and histo-pathology of the reproductive organs of calves from abortion infected herds. There are a few investigators of abortion disease who contend that calves from infected herds frequently acquire abortion infection during fetal life or early post-parturient life and harbor this infection throughout calf-hood and abort during their first pregnancy as a result of such infections. A knowledge of the facts in this particular phase of the abortion problem is of great practical value. During the past year opportunity has been afforded to study the bacteriology and histo-pathology of several calves from infected herds. At this time we do not care to publish a detailed report of these cases but may say that only in one case studied have we obtained evidence of the presence of living micro-organisms in the reproductive organs. In no case have we found any evidence that an inflammatory condition of the reproductive organs due to bacterial infection exist. The one case excepted above is a Holstein calf prematurely delivered July 9th, 1921, was due August 23, 1921. The calf was thrifty during the first six weeks of life and then began to decline. It was killed October 12th, 1921. In the liver of this calf were sixteen to eighteen sharply circumscribed abscesses varying from ten to fifty millimeters in diameter containing a thick creamy pus. Bact. lipolyticus type C was isolated from these abscesses. The same organism was isolated from the uterus. There was no evidence of any reaction (inflammation) in the uterus resulting from this organism. This problem will be continued during the ensuing year and we hope to have sufficient material in the not distant future to warrant publication of the results.

Mr. Huddleson of the Department of Bacteriology has kindly made all bacteriological examinations in the cases referred to above.

Respectfully submitted,
E. T. HALLMAN,
Animal Pathologist.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE SECTION OF BACTERIOLOGY

Director R. S. Shaw,
College.

Dear Sir: The past year has seen no changes in either personnel or projects in this Division. For the first time since our entry into the Great War we are able to report uninterrupted progress in all lines with a complete staff of well qualified men. It is needless to say that our achievements even in the very limited fields explored have themselves been limited, seriously and uneconomically so, by lack of substantial appropriations for men and materials. We should have numerous assistants working under the direction of the mature well trained experts in the various fields of bacteriology. A plan involving the use of numerous younger men and women should be very helpful to us, economical to the State, and satisfactory to the aspiring young assistant. Of course they would come and go, but that need cause no embarrassment to either party concerned. Both the human element and the work itself would be properly considered.

Mr. Tweed's time has been distributed amongst teaching, studies of various phases of fermentation and research on "The effect of diseases of the cow upon the milk." (Adams 1a.)

REPORT OF RESEARCH ASSOCIATE R. L. TWEED

Under Adams 1a I have continued the following phases of the project as related to infectious abortion.

1. Studies upon the significance of high cellular count of milk from *Bacterium abortus* infected udders as compared with that from non-infected udders.
2. A study of the teats as an avenue of *Bact. abortus* infection of the udder.
3. Feeding experiments with *Bact. abortus* infected milk.
4. Efforts to devise better methods for studying the presence of *Bact. abortus* in the udder.
5. Bacteriological and pathological studies of *Bact. abortus* infections of the udder.

Under the last phase of this project Graduate Assistant Otto H. Friedemann this year submits a thesis for the master's degree, "A study of the nature of *Bact. abortus* infection of the udder."

My work in relation to fermentation has been as follows:

Vinegar: From July 1, 1921, to June 30, 1922, 130 requests for vinegar cultures were received, 116 yeast cultures were sent out and 90 cultures of acetic bacteria not including two gallons of culture sent to a Michigan vinegar company for starting generators, and 40 lots of chemicals for making honey vinegar. Fifty-four of the requests for vinegar cultures were from outside the State.

The decrease in requests for vinegar cultures during the past year was probably due to the shortage of apples last fall.

Seventy-six samples of vinegar were tested, the analysis of which are tabulated herewith:

Sample No.	Acetic Acid.	% Alcohol by wt.	Sugar.	Color.	Flavor.	Remarks.	Suggestions.
205	7.0	......	......	Amber	Good	Clear	May standardize to 4%.
206	7.0	......	......	Amber	Good	Clear	May standardize to 4%.
207	4.1	.31	+−	Amber	Clean acid	New vinegar	Ventilate and keep warm.
208	1.4	1.48	+−	Amber	Good	Clear	Inoculate with Bact. aceti.
209	2.1	1.05	+	Light amber	Clean	Clear	Ventilate and inoc. with Bact. aceti.
210	1.0	1.43	−	Light amber	Clean acid	......	Ventilate, keep warm, inoculate with Bact. aceti.
211	2.9	.99	+	Amber	Clean acid	Clear	N. G.
212	2.6	1.4	+	Amber	Clean acid	Clear	Keep in warm place, allow air to circulate.
213	3.3	1.0	+	Amber	Clean acid	Clear	Ventilate and keep warm.
214	2.8	1.34	+−	Amber	Clean acid	Clear	Ventilate and keep warm.
215	2.7	1.48	+	Amber	Clean acid	Turbid	Ventilate and keep warm.
216	4.4	.94	+−	Amber	Clean acid	O. K	Of market standard.
217	3.8	1.4	+	Amber	Clean acid	Little weak	Keep in warm place.
218	2.9	4.8	+−	Amber	Clean acid	Little weak	Ventilate and keep warm.
219	.8	2.69	−	Light amber	Clean	Low in sugar	May add sugar or molasses and use for home.
220	2.1	1.91	+	Light amber	Clean weak acid.	Clear	Ventilate and keep warm.
221	......	1.22	......	Amber	Watery	......	N. G.
222	2.9	2.05	+−	Light amber	Clean acid	Clear	Ventilate, keep in warm place, inoc. Bact. aceti.
223	.6	4.81	+−	Light amber	Unclean	Turbid	Inoculate with Bact. aceti. and keep in warm aerated place.
224	2.6	2.13	++	Cloudy	Clean acid	Cloudy	Ventilate and keep warm.
225	3.5	2.2	++	D. amber	Good	Clear	Keep warm.
226	3.6	Sample too small.	++	Amber	Clean acid	Clear	Ventilate and keep warm.
227	6.1	......	−++	Amber	Clean acid	Clear	May standardize to 4%.
228	3.0	Sample too small.	++	Amber	Clean acid	Clear	Ventilate and keep warm.
229	2.5	Sample too small.	++	Amber	Clean acid	Clear	Ventilate and keep warm.
230	4.1	Sample too small.	+	Amber	Clean acid	Clear	Market standard.
231	1.2	Sample too small.	......	Light amber	Flat	Clear	N. G.
232	3.6	3.34	+−	Light amber	Clean	Clear	Inoc. Bact. aceti. and keep warm.
233	2.4	4.4	+	Dark amber	Clean	Clear	Inoc. Bact. aceti. and keep warm.
234	0	8.97	......	Dark amber	Alcoholic	Clear	Inoc. Bact. aceti. aerate and keep in warm place.
235	.0	8.97	......	Dark amber	Alcoholic	Cloudy	Inoc. Bact. aceti., keep warm and aerate.
236	1.5	4.9	......	Amber	Alcoholic	Cloudy	Inoc. Bact. aceti, keep warm
237	5.2	......	......	Light amber	Clean acid	O. K	May standardize to 4%.
238	3.3	......	......	Amber	Acid	Clear	Ventilate and keep warm.
239	5.5	......	......	Amber	Acid	Clear	May standardize to 4%.
240	3.1	......	......	Amber	Acid	Cloudy	Ventilate and keep warm.
241	5.2	......	......	Light amber	Clean acid	O. K	May standardize to 4%.

Sample No.	% Acetic Acid.	% Alcohol by wt.	Sugar.	Color.	Flavor.	Remarks.	Suggestions.
242	5.2	...	...	Light amber	Clean acid	O. K	May standardize to 4%.
243	3.8	...	...	Amber	Sl. bitter	Clear	Ventilate and keep warm.
244	4.1	...	...	Light amber	Acid	O. K	Market standard.
245	5.8	...	...	Dark amber	Acid	O. K	May standardize to 4%.
246	5.9	...	...	Light amber	Acid	O. K	May standardize to 4%.
247	5.8	...	...	Light amber	Acid	O. K	May standardize to 4%.
248	5.7	...	...	Light amber	Acid	O. K	May standardize to 4%.
249	3.5	...	...	Light amber	Clean acid	Clear	Ventilate and keep warm.
250	4.8	...	...	Light amber	Clean acid	Clear	May standardize to 4%.
251	6.0	...	...	Amber	Acid	O. K	May standardize to 4%.
252	5.2	...	...	Amber	Acid	O. K	May standardize to 4%.
253	6.0	...	...	Light amber	Clean acid	O. K	May standardize to 4%.
254	6.2	...	...	Light amber	Clean acid	O. K	May standardize to 4%.
255	6.4	...		Light amber	Clean acid	O. K	May standardize to 4%.
256	5.0	...	...	Light amber	Clean acid	O. K	May standardize to 4%.
257	5.4	...	...	Light amber	Clean acid	O. K	May standardize to 4%.
258	6.5	...	...	Light amber	Clean acid	O. K	May standardize to 4%.
259	5.0	...	...	Light amber	Clean acid	O. K	May standardize to 4%.
260	3.8	Not tested	...	Amber	Acid	Clear	Ventilate and keep warm.
261	3.8	Not tested	...	Amber	Bitter	Sent in medicine bottle.	Keep warm, allow air to circulate.
262	3.2	Not tested	...	Amber	Bitter	Sent in medicine bottle.	Keep warm, allow air to circulate.
263	3.8	Not tested	...	Amber	Bitter	Sent in medicine bottle.	Keep warm, allow air to circulate.
264	1.2	1.19	...	Amber	Bitter	Vinegar eels	N. G.
265	3.8	...	...	Amber	Acid	Clear	Ventilate and keep warm.
266	1.4	Sample too small.	...	Amber	Flat	Clear	Send larger sample.
267	3.2	Sample too small.	...	Light amber	Acid	Cloudy	Ventilate and keep warm.
268	4.3	...	...	Amber	Acid	O. K	Market standard.
269	6.4	...	...	Amber	Acid	O. K	May standardize to 4%.
270	1.7	Sample too small.	...	Amber	Flat	O. K	Send larger sample.
271	2.9	1.4	+−	Amber	Good	Clear	Ventilate and inoculate.
272	0.2	5.3	...	Amber	Good	Clear	Ventilate and inoculate.
273	3.0	Sample too small.	...	Amber	Clean	Clear	Send larger sample.
274	4.5	...	...	Amber	Bitter	Sent in medicine bottle.	O. K.
275	2.3	1.89	+−	Amber	Clean	Clear	Keep warm and ventilate.
276	1.7	1.12	...	Amber	Flat	Cloudy	Filter, pasteurize and reinoculate.
277	1.2	5.67	+−	Amber	Flat	Clear	Keep warm and ventilate.
278	.46	9.12	+−	Amber	Flat	Clear	Inoculate with Bact. aceti. and ventilate.
279	3.8	...	...	Dark amber	Bitter	Cloudy	Ventilate and keep warm.
280	2.7	...	+−	Light amber	Good	Clear	Ventilate and keep warm.

Twenty-six out of the 76 samples analyzed were found to be of market standard (4 per cent) or above, while only three were found to be worthless. The remaining 47 samples theoretically would make good vinegar if optimum conditions were provided for the vinegar organisms.

Several inquiries have been received regarding the preserving of sweet cider. An article, "On Home Preservation of Fruit Juices," was written and published in the May number of the Michigan Quarterly Bulletin, 1922, in which pasteurization was recommended.

Silage Poisoning: Nine samples of silage, five samples of ground feed, and one each of beet pulp and tankage were received for analysis. These were either suspected of poisoning stock or merely sent in to determine their suitability for stock food. *B. botulinus* was not found in any of the samples. Five samples of silage were extremely mouldy and were recommended as undesirable for stock food.

Flax Retting: Miss A. Trevithick, working under the combined direction of Mr. R. L. Davis, of the United States Department of Agriculture, and myself has made marked progress in developing pure cultures of organisms, capable of retting flax of good quality. Miss Trevithick has accepted a position with the United States Department of Agriculture and will continue her research on the pure culture control of flax retting at this Station during the coming year.

The accompanying table gives data on food samples analyzed during the past year:

FOOD SAMPLES

Food.	Condition on receipt.	Method of of canning.	Organisms present.	Recommendations.
Canned cider......	"Springers"........	Cold-pack....	Spore-forming rod, growing best at 55°C.	Use of higher temperature in processing and more rapid cooling following processing.
Canned corn......	Soft, putrid odor....	Water - bath cold-pack	Many gram + and spore-forming organisms.	Use of steam pressure cooker.
Pickles...........	Soft and cloudy.....	....	No organism found capable of producing softness. Acidity high.	
Milk..............	Red................	....	Color not due to microbial growth but to blood.	Discard milk from affected quarters.
Canned asparagus..	Liquid cloudy......	Unknown.....	Gram + and rods animal inoculation negative.	
Canned tomatoes...	Leaky, gas present...	Open kettle...	Slender rod with terminal spores.	Use better rubbers and covers to seal jars.
Bread............	Ropy and sour......	....	Isolated organisms of B. mesentericus group and traced to potatoes used in sponge.	Sterilize baking utensils and use better potatoes.

I have also during the past year made 23 autogenous bacterins for the treatment of boils and chronic infections. Eighty quarts of milk inoculated with *Bacillus acidophilus* for the treatment of intestinal disorders have been prepared. Very favorable results have been reported from both the bacterins and the milk. [Robert L. Tweed.]

Mr. G. L. A. Ruehle has devoted two-thirds of his time to research and one-third to teaching along lines related to his investigations. His major project is one of fundamental importance to the industry of manufacturing edible fats.

REPORT OF RESEARCH ASSOCIATE G. L. A. RUEHLE

The work of a popular nature consisted in answering letters of inquiry relative to dairy and creamery hygiene and inspection and analysis of the milk supply of East Lansing. Several minor problems have been studied during the past year as follows:

I. *Examination of a commercial brand of pepsin for the cause of a bad odor and flavor.*

On June 15, 1921, we received an inquiry from a commercial house in Detroit asking if we could help them to determine the cause of a musty odor in their pepsin. On June 20 we received the sample, a pepsin powder of 1 to 10,000 strength. This had an odor which resembled decomposing animal matter, suggestive of the odor of a packing house. The taste also suggested decomposing animal matter as well as being slightly acid and salty. A microscopical examination revealed bacteria in large numbers, including both long and short rods and diplococci. Starting with a 10 gram sample the material was plated out on lactose agar in dilutions from 1 to 10 to 1 to 1,000. The count four days later was 398,000,000 bacterial colonies per gram. The plate cultures had a sharp ammoniacal odor, pervaded by a putrefying odor similar to if not identical with that of the original pepsin. (A sample of Merck's pepsin of unknown age was also examined for comparison. This contained 100 bacterial colonies per gram although a microscopical examination revealed many rod-shaped bacteria.)

The plates were overgrown to such an extent that pure cultures could not be fished satisfactorily, so that loop dilution plates were made of both samples of pepsin and cultures fished from these, as follows:

Merck A—A large, white, irregular surface colony, consisting of large Gram positive rods with cylindrical spores, many of which were free.

Merck B—A small, nearly round, light greenish-yellow surface colony, consisting of small Gram negative rods. No spores observed.

Merck C—A large, nearly white, irregular, sub-surface colony, consisting of large Gram positive rods with cylindrical spores, some of which were free. Probably the same as Merck A.

B. A.—A large white, nearly round, raised, pultaceous surface colony, consisting of slender Gram positive rods with oval central spores in clostridial sporangia.

B. B.—A large, round, light greenish-yellow surface colony, consisting of short rods, some Gram negative and some Gram positive; no spores seen.

B. C.—A small, yellow, lens-shaped, sub-surface colony, consisting of short rods, some Gram positive and some Gram negative. No spores seen.

B. D.—A large, irregular, nearly white, surface colony. Veil-like with lacy edge, consisting of long, slender rods and filaments, which stained faintly Gram positive. Round terminal or sub-terminal spores, with tags of protoplasm on the end of the sporanginum containing the spore.

These various cultures were inoculated singly and in combinations with each other into sterile beef infusion and allowed to incubate. Only those cultures containing "B. B." had the putrefying odor of the original pepsin so it was concluded that "B. B." was the responsible organism.

Some months later a second sample of pepsin from the same company was examined. The company stated that they had been trying out new methods of manufacture. This sample was a spongy scale pepsin of 1–10,000 strength. It had a salty, not unpleasant taste and lacked the decomposing animal odor of the previous sample. This sample when plated gave a count of 1,830,000 bacterial colonies per gram and the culture plates smelled strongly of ammonia and putrid animal matter. The following cultures were isolated from these plates:

D. A.—A soft, round, large, nearly white glistening, surface colony, many colonies on plate consisting of large rods in chains with square ends. Spores not observed.

D. B.—A small, opaque, irregular, sub-surface colony, many on plates. Smaller, more slender rod than D. A. No spores seen.

D. C.—A small, yellow, lens-shaped, sub-surface colony numerous on plates. A mixture of short and long rods. Nearly round free spores observed.

When these cultures were inoculated into sterile beef infusion alone and in combinations all flasks had the putrefying odor except the one with D. C. alone.

Later two other samples of pepsin were received from the company and examined for their bacterial counts. Spongy Granular Pepsin No. 123 contained 1,300 bacterial colonies per gram and Rx 10,364 contained 2,800 bacterial colonies per gram. No bacteria were seen in smears made from either of these pepsins. Both had a salty, slightly acidulous taste but no bad odor or taste. The following cultures were isolated:

Sp. A.—(From Spongy Granular Pepsin No. 123.) A large, irregular, wrinkled, white, surface colony. Predominant flora. A large spore-bearing rod. The plates seemed to be seeded with practically pure cultures of this organism.

Pv. A.—A small lens- shaped sub-surface nearly white colony. Numerous on plates. Consisted of very small rods—no spores observed.

Pv. B.—A large, nearly round, white, soft colony. Not numerous. A large rod with cylindrical spores which were shorter but thicker than sporangia.

Pv. C.—A large, irregular, white, wrinkled, tough surface colony. Not numerous on plates. Shorter, fatter rods than Pv. B., but with spores of same shape and size. Sporangia club shaped with spores deeply imbedded. Sporangia larger than rods in some cases.

Pv. D.—Small, round, white surface colony. Numerous on plates. A large rod—no spores observed.

In the letter accompanying these two samples there was a request that we state whether the organisms contained in the pepsin were capable of producing tyrosin from proteid material. They had had considerable tyrosin formed in the process of manufacture and wished to find the cause of its formation.

In order to test this point, the organisms previously fished were inoculated into sterile skim milk and incubated for 14 days at room temperature. Peptonization was noted and is recorded below by plus and minus signs, four plus being practically complete peptonization, three plus, two plus and one plus being various degrees of peptonization, while minus means that no peptonization was observed.

Merck A. + + + +
Merck B. –
Merck C. + + + +
B. A. +
B. B. –
B. C. +
B. D. –
D. A. + + +
D. B. + +
D. C. –
Sp. A. + + + +
Pv. A. + + + +
Pv. B. + + + +
Pv. C. + + + +
Pv. D. –

The samples were then shaken and tested qualitatively for tyrosin by Folin and Denis' Reagent. In recording the results I have used one plus sign to indicate the weakest shade of blue, which corresponds to a negative test, as is shown by the fact that uninoculated milk gave a light shade of blue with the reagent. The following are the results of this test:

Uninoculated milk + (negative)
Tyrosin in water + + + +
Tyrosin in milk + + +
Typtophane in water + + +
Typtophane in milk + +
Merck A. + + +
Merck B. + (negative)
Merck C. + +
B. A. + (negative)
B. B. + +
B. C. + +
B. D. + (negative)
D. A. + +
D. B. + +
D. C. + (negative)
Sp. A. ++ +
Pv. A. + + +
Pv. B. + + + +
Pv. C. + + + +
Pv. D. + (negative)

It will be observed that typtophane gives the reaction as well as tyrosin. According to Abderhalden oxy-typtophane and l-oxyprolin also give a blue color with this reagent. I know of no test for the two latter substances but I performed a test for typtophane with bromine water. The following results were secured:

Merck A. +
Merck B. –
Merck C. + +
B. A. –
B. B. –
B. C. –
B. D. –
D. A. +
D. B. +
D. C. –
Sp. A. + +
Pv. A. +
Pv. B. +
Pv. C. + +
Pv. D. –
Negative control –
Positive control with milk + + + +
Positive control with water+ + + +

From the foregoing it will be seen that a more specific reagent was necessary to determine whether the substance giving a blue color with Folin and Denis' Reagent was in reality tyrosin or something else. In some of the cases it is clearly due to typtophane, so a glycerin extract of tyrosinase from wheat bran was prepared. This, along with some of the bran itself, was added to a portion of each sample and to suitable positive and negative controls. The following are the results:

Weak solution of tyrosin (positive control) +
Weak solution of tyrosin in milk (positive control) +
Milk alone (negative control) –
Milk cultures, all –

The above extract of tyrosinase was so weak, however, that little reliance was placed on the results. Accordingly the cultures were held for a few weeks longer while an attempt was made to obtain some mushrooms from which a more active extract of tyrosinase could be prepared. This was difficult to do in mid-winter since only dried specimens of the mushrooms could be obtained. Finally a glycerine extract of *Russula densifolia* was prepared which was fairly active but which also blackened slightly without the addition of tyrosin, indicating there was a trace of tyrosin present in the mushroom. The following results were obtained: (a ± indicating that the color was no darker than the negative controls while the + signs indicate the degrees of color obtained.)

Negative control (water) ±
Negative control (milk) ±
Positive control (tyrosin dissolved in water) + + + +
Positive control (tyrosin dissolved in milk) + + + +

Cult. B. A.	+ + + +	Cult. Pv. A.	+ + + +
Cult. B. B.	± (negative)	Cult. Pv. B.	+ + +
Cult. B. C.	+ + + +	Cult. Pv. C.	+ + +
Cult. B. D.	+ +	Cult. Pv. D.	+ + + +
Cult. D. A.	+ + + +	Cult. Sp. A.	+ +
Cult. D. B.	+ + +	Cult. Merck. A.	+ + + +
Cult. D. C.	+	Cult. Merck. B.	+ + + +
		Cult. Merck. C.	+

In four of the cultures—"Sp. A.," "Pv. A.," "Pv. B.," and "Pv. C."—the production of tyrosin was great enough to be observed by the naked eye as fine white tufts of silky crystals in the bottom of the flasks. Some of these were separated out mechanically and were proved to be tyrosin by microscopic and chemical tests (Moerner's Reagent, Folin and Denis' Reagent and Piria's sulphuric acid test).

There is no doubt that all of these organisms, except "B. B.," "D. C." and "Merck C." are capable of producing tyrosin from casein. Some of them also produce tryptophane. The few discrepancies in the results obtained by the biochemical test should be disregarded because of the fact that, as tyrosin is nearly insoluble, it is very easy to obtain a negative result even when there is enough tyrosin present to see it with the naked eye.

While these experiments were in progress two further samples of pepsin were received from the same company with a request for a bacteriological analysis. Mr. Keyt, a student assistant, plated out the samples and obtained counts of 620 per gram from one of the pepsins and 160 per gram from the other.

It is interesting to note from the above that commercial pepsins may be heavily contaminated with organisms which can decompose protein, splitting them to amino acids. Even when special attempts were presumably being made to produce a sterile product, there were still undesirable organisms present though in small numbers.

II. *Examination of a brand of filled evaporated milk for the cause of a bitter flavor.*—A firm manufacturing filled evaporated milk requested us to ascertain the cause of a bitter flavor in the product, which was put up in cans and was supposed to be sterile. They stated that their own bacteriologists had pronounced the product contaminated with heat resistant organisms. They also stated that the trouble appeared rarely and then only in the baby size.

The product consisted of evaporated skim milk to which cocoanut oil had been added and the whole heated in the cans for the purpose of sterilizing.

When the samples arrived one can was plated out on lactose agar both aerobically and anaerobically, using the pyrogallic method for the latter. After 10 days' incubation at room temperature, the aerobic plates gave a count of 240 per cc. and the anaerobic plates a count of 35 per cc. Strict anaerobes were not found as the cultures fished from the anaerobic plates grew well on agar slants. The following cultures constituted the predominant flora on the aerobic plates:

A. I.—A large, white, wrinkled, raised, dull, sticky surface colony. A large rod with oval spores, many of which were free. Spores larger in diameter than the vegetative rods. Spores eccentric.

A. II.—A yellowish-white, large, round, wrinkled glistening colony of cheesy consistency. Same microscopic appearance as A. I.

A. III.—Small, oval, brownish sub-surface colony. Predominant form on plates. Large rod, free spores which were short and cylindrical.

A. IV.—Small brownish, irregular, dull, surface and slightly sub-surface colonies. Large rods, with spores of same appearance as A. III.

The above organisms were inoculated in duplicate into some sterilized, filled evaporated milk which had not turned bitter. After 5 days one set of the duplicate cultures was tasted but no change in taste was noted. After 27 days the duplicate set was tasted and all the inoculated samples were intensely bitter while the control tube was not bitter.

In the meantine, I had Mr. Segelin plate out another can on milk powder agar, the plates being held under aerobic conditions. He obtained a count of 2,000 colonies per cc. and he isolated six organisms:

C. 1.—A pear shaped colony 2 mm. in diameter, white to gray, with clearing around the colony. Large rod-spindle-shaped sporangia, with spores placed eccentrically.

C. 2.—Radiating colony 2 mm. in diameter. Straight rod with rounded ends, 2-4 cc. long. Spore former.

C. 3.—Round, white colony, smooth, rained. Large micrococci, occurring in irregular groups, as diplococci and as tetrads.

C. 4.—Nearly round, white colony with wavy edge similar to C. 1.

C. 5.—Round, white colony. Similar to C. 1.

C. 6.—Small, lens-shaped-yellowish colony. Resembles C. 2 in microscopic appearance.

These were inoculated into sterile filled evaporated milk and the cultures were tasted at the end of 17 days. All produced a bitter flavor in the milk while the uninoculated control tubes did not taste bitter.

III. *Examinations of "Ever Fresh" milk.*

A number of bottles of this product were submitted to me for examination as to sterility. The milk was put up in 14 oz. dark brown bottles, sealed with a crimp cap. On the label is the picture of a cow-head and a bottle of Ever Fresh Milk with the legend "Her ideal realized." Below is the following statement: "Milk that keeps. Ever Fresh Milk. Pasteurized in the bottle. Pure cows' milk. Germless; unadulterated; keeps fresher and longer when opened than ordinary milk; being easily digested and standardized, it is a perfect and balanced food for infants, especially valuable for invalids and ideal for children and adults; contains all essentials of a perfect diet. Chevalley Ever Fresh Milk Products Co., Portland, Oregon."

The bottle was opened after flaming the crimped cap and neck of the bottle. It was plated at once on lactose agar in a series of dilutions in triplicate. The plates after 7 days' incubation showed from 1 to 5 colonies per plate. These were regarded as probably the result of contamination in plating. Direct microscopic examination of the milk by Breed's technique revealed no bacteria. Considerable cellular debris—nuclei and pieces of nuclei of body cells—were found.

Unstained milk placed under coverslips and examined under the microscope showed very tiny fat globules not clumped as in ordinary milk. This, together with the fact that it was extremely easy to restore a perfect emulsion upon shaking, led to the conclusion that this was homogenized milk. On tasting the milk, the custard-like taste of repeatedly pasteurized milk was noticeable. Like all overheated milk, this product tasted slightly, though not unpleasantly, astringent. The remainder of this bottle of milk was transferred aseptically to a series of sterile test tubes and held at room temperature to see if it would sour. After 4 days it was still sweet.

Another bottle was opened and tested for acidity. Five cc. required 2 cc. $\frac{N}{20}$ NaOH. This is equivalent to 0.18% acid calculated as lactic acid. This milk was tested by the Dairy Department for butterfat by the Babcock method and found to contain 3.2% fat.

Two other bottles were held for 3 months, one in the ice box and the other in the 37°C. incubator. At the end of this period, the milk held in the ice box was still fluid and sweet while the milk held in the incubator was curdled and had wheyed off. This tasted only slightly sour and unpleasant. Acidity tests made on both milks give the following results:

37° C milk, 5 cc. = 6.68 cc. $\frac{N}{20}$ Na OH.
Ice Box milk, 5 cc. = 2.25 cc. $\frac{N}{20}$ Na OH.

When plated in triplicate on lactose agar, the bacterial counts after six days incubation at room temperature were as follows:

37° C milk gave 52,000 colonies per cc.
Ice box milk gave 40 colonies per cc.

A number of spore bearing rods were isolated from each milk but as it was impossible to reproduce the type of curd in the original, by ordinary cultures, anaerobes were suspected. Accordingly, several tubes of sterile litmus milk were inoculated with loopfuls of ice box Ever Fresh Milk and covered with an 18 mm layer of sterile paraffin. After incubation at room temperature for a week, the paraffin plug in one of the tubes was raised about 12 mm. and some of the milk was above the plug. That above the plug was acid in reaction, while that below showed the litmus reduced to the leuco compound. On plating,and fishing the colonies which had grown anaerobically, four cultures were obtained and grown by anaerobic methods on lactose agar. These produced gas from the lactose in the agar so that it was blown full of holes and separated into sections. The colonies on the plates were small, the surface colonies being round and the sub-surface being lens-shaped. All were sporebearers with large round spores terminally placed in a slender rod. The spores were larger in diameter than the rods giving the appearance of a nail with a round head. These grew well on agar slants in Giltner H-tubes containing NaOH and pyrogallic acid in the second tube of the H. Two of them failed to grow when transferred to an ordinary aerobic slant while two grew well on the slant.

From the foregoing tests it is reasonable to conclude that Ever Fresh Milk while very low in germ content cannot be said to be sterile.

IV. *Examination of Spoiled Beet Sugar for Microorganisms.*

Just before going on my vacation last summer a sample of beet sugar was submitted to me for analysis for microorganisms by a sugar company. The sugar was sticky or waxy in appearance. It was stated by the company's chemist that the sugar contained invert sugar and the question was whether there were organisms present which could invert sucrose.

Some of the sugar was dissolved in sterile water and then centrifuged. After centrifuging, the sediment was examined microscopically. This examination revealed some bacteria and much debris of a mold-like character, i. e., mold spores and fragments of mold hyphae. The sugar was then plated out by the loop dilution method and the plates turned over to Dr. Snyder, who also made some further cultural examinations of the sugar. He isolated four species of molds and three species of bacteria from the sugar, the most predominant species found being a *Penicillium* species capable of producing acid from sucrose. He was of the opinion that the acid caused the inversion of the sugar. Of course, the presence of molds, in itself, could account for the inversion since many species of molds contain invertase. Kopeloff has shown that even mold spores, without the presence of hyphae, are capable of inverting sucrose.

It developed later that this sugar was from a shipment which was consigned to a warehouse for storage and which became sticky and then caked. The warehouse people submitted a sample of the sugar in a sugar sack. This contained some hard lumps and some apparently unchanged sugar. Starting with a 10 gram sample of the caked sugar, it was plated out in dilutions of 1/10 to 1/10,000. A count of 60 bacterial colonies per gram was obtained. Only one Penicillium colony and one Aspergillus colony developed on the 1/10 dil. plates, the plates of the other dilutions being free of mold growths and practically free of bacterial colonies.

Some of the sticky sugar, which had been held over from last summer in a sterile petri plate was also plated at the same time. A count of 2,000 molds per gram and 77,000,000 bacterial colonies per gram was obtained. The molds were identified as *Penicillium* species and *Aspergillus* species. The bacterial colonies consisted of apparently only one species. This formed a small round, white, glistening surface colony and a small, yellowish, lens-shaped, sub-surface colony. The colonies consisted of small rods, many of which contained oval spores placed near one end of the sporangia, the spores being about twice the width and taking up most of the length of the sporangia.

Experiments were also conducted with some of the sugar which had not caked to determine how soon caking would take place after wetting and also if heavily inoculating with the microorganisms isolated above affected the results appreciably. For this purpose some of the uncaked sugar was placed in small sacks made of cheese cloth, and the sugar dipped into distilled water until thoroughly wet when they were hung up to dry, some at room temperature and some at 37°C. Another set was also prepared in the same way, but instead of being dipped in distilled water, they were dipped in distilled water containing the growths—mold and bacterial—from the plates from which the Aspergillus, Penicillium and the peculiar spore forming bacillus were isolated. The following scheme will illustrate the test:

1. Uninoculated sugar—dry.........Room temperature.
2. Uninoculated sugar—dry.........37°C.
3. Uninoculated sugar—wet.........Room temperature.
4. Uninoculated sugar—wet.........37°C.
5. Inoculated sugar.................Room temperature.
6. Inoculated sugar.................Room temperature.
7. Inoculated sugar.................37°C.
8. Inoculated sugar.................37°C.

In 24 hours the bags were examined. All of those sugars which were wet either with distilled water or with culture were hardened on the outside of the bags, although still soft on the inside. Those stored at 37°C were harder than those at room temperature. This seems to indicate that the hardening was due to the effect of drying of the wet sugar. This conclusion is further strengthened by the fact that the sugar in all of the wet bags became progressively harder as time went on. Drippings from the bags were submitted to the Chemistry Department of the College for chemical tests for invert sugar. Both the methyl blue test and Fehling's test for monosaccharides indicated that invert sugar was present in all of the samples.

An attempt was made to determine whether the microorganisms isolated as described above could grow and cause an inversion of the sucrose in a sterile sugar solution. It was found that both molds made some growth, visible to the naked eye in three weeks and caused a partial inversion of the sucrose, since a test for monosaccharides was obtained with Fehlings' solution. In connection with the sterilization of the sucrose solution some interesting and suggestive data were secured. It was found to be practically impossible to sterilize sucrose either as a solution in the autoclave or as a dry sugar in the hot air sterilizer without inverting it. In the latter case, sterilization at 125°C to 130°C for a long period was attempted, but a test for monosaccharides was obtained, nevertheless. This suggests the futility of making sucrose broth and sterilizing in the ordinary manner. In our experiments above a sterile sugar solution was made by filtering the syrup through a Berkfeld filter.

V. *Examination of cheese to determine if it had poisonous properties.*

Some cheddar cheese was brought in by a physician, who stated that persons eating the cheese had become ill with severe watery diarrhea, vomiting and cramps. Persons in the same family who had not eaten of the cheese had remained well. This piece of cheese which was as large as a hen's egg was ground and mixed with bran and fed to a hen, who ate it all at one time. The hen was kept under observation for 3 days but no signs of poisoning were evident. Further investigation showed that the manufacturer had sold all of the cheese locally, but had not received any other complaints.

VI. *Examination of two samples of cream for undescribable flavors.*

The first was a sample of cream with a putrid flavor. This was plated out and a number of bacteria and molds were isolated, among them being a spore forming rod, an Actinomycete and an Oöspora. Inoculation of these into sterile milk showed that the putrid flavor was due to the spore-bearing bacillus.

The second was a sample of cream with a peculiar off-flavor, which I can only describe as "sickish", although I realize that this is not descriptive. When it first arrived it was sour and no off-flavor could be detected, I inoculated some sterile milk with 1cc. of the cream and placed the inoculated milk in the ice box for 3 days. At the end of this time the peculiar flavor described above had developed. I had Mr. Small plate out this material by the loop dilution method. He isolated six cultures, which were inoculated alone and with *Bact. lactis acidi* into sterile milk, the *Bact. lactis acidi* being inoculated 24 hours after the other organisms had been inoculated. All of these organisms produced off-flavors either alone or in conjunction with *Bact. lactis acidi*, but two of them, which are undoubtedly identical, reproduced the peculiar flavor mentioned above. This organism is a very short oval rod, in fact it is almost a coccus. It produces a small, round, white, elevated, glistening, surface colony and a small, round, grey, dull, sub-surface colony.

VII. *Examination of Pink Buttermilk.*

Some pink buttermilk was sent in for a bacteriological examination. A chemical examination had failed to show any cause for the red color, which appeared sporadically. Upon culturing, a yeast and *Bact. lactis acidi* were found, although a microscopic examination of the buttermilk itself showed the presence of rod shaped bacteria and the usual *Bact. lactis acidi*. Inoculation of the yeast alone and in combination with *Bact. lactis acidi* failed to reproduce the color.

VIII. *Off-flavor in a sample of milk.*

A sample of milk was brought to the laboratory by a consumer, who stated that the milk frequently had a disagreeable flavor and odor. Probably the term "sickish" would apply as well to this as to the cream described above under VI. The odor was similar to that of a cow's breath. Among other organisms isolated from this milk was a very small organism. It was a short rod, almost short enough to be called a micrococcus. It produced a light yellow, soft surface colony. This, when inoculated into sterile milk, produced a putrid, sickish flavor and odor.

IX. *Milk suspected of making school children sick.*

Two samples were brought to the laboratory, one being milk of that day and one the milk of the previous day. Both milks were plated and the plates counted. The fresher milk had a bacterial count of 690,000 colonies per cc. and the older milk a count of 5,690,000 colonies per cc. A study of the flora revealed the fact that it was not that of normal milk. The plates on which the counts had been made had a very putrid odor. No further work was done with these samples.

X. *Yeasty Cream in a Creamery.*

A sample of cream was sent to the laboratory by a farmer's co-operative creamery association to determine the cause of a yeasty flavor and a foamy condition of the cream. Microscopic examination revealed the presence of enormous numbers of yeast cells and organisms resembling *Bact. lactis acidi* in microscopic appearance. The company requested me to visit their plant. I found everything apparently in a sanitary condition at the plant so a visit was made to the patron bringing the yeasty cream. It was found that he was not making any attempt to sterilize his utensils or to cool his cream. The cream was pooled from day to day and delivered twice a week. The farmer was told how to sterilize his utensils and cool his cream. Favorable results were reported.

In connection with the research work on the Adams Fund Project 1b, I have been studying, as I proposed to do last year, the microflora of off-flavored butters, some of which were obtained from the United States Department of Agriculture Inspector in Chicago and some were butters from various sources including some experimental butters. About 200 such cultures have been isolated and are being studied as to their ability to produce off-flavors in sterile whole milk. It is planned to study these organisms and identify or describe them and to make experimental butters inoculated with those capable of producing off-flavors in milk.

Besides the work mentioned above some studies are being made upon the ability of spores and dead bacterial cells to release enzymes significant for the spoilage of butter. This work has not progressed to the stage where definite statements can be made.

In conclusion I should like to quote the last two paragraphs of my report last year. I feel more strongly on this matter now than I did then. The work on enzymes has called for a considerable number of chemical analyses which could have been done much better by a chemist than by a bacteriologist. The work on metallic salts in butter has been delayed while waiting for favorable action on my recommendation of last year, which follows:

"I suggest that it would be well to ask the Chemistry Section to co-operate with us on this problem, even to the extent of becoming jointly responsible for the project (Adams 1b). I find it impracticable to do the necessary chemical work myself. At the present time it is desirable to determine whether certain off-flavored butters have appreciable amounts of iron, copper, lead or zinc salts present and, if so, to what extent. Some of the work which I have done, and work done at other places, suggests that these salts are the exciting cause of certain off-flavors, notably metallic and tallowy flavors. A large number of samples of butter should be examined for their content of these metals and experiments should be performed to show the amounts required to produce the results, the chemical reactions taking place and the conditions which determine what takes place.

"It would be advantageous also to have the Dairy Section partly responsible for the project, since they are in closer touch with the buttermaking industry and could give the work a practical direction and interpretation, as well as assist us in the manufacture of experimental butters and in the judging of the butters being studied." [G. L. A. Ruehle.]

Dr. Snyder has taught the Short Course Students in General Bacteriology and has supervised the work of Mr. Davenport until this spring. He has also directed the work of graduate students in Soil Bacteriology. Most of his time has been devoted to his major problem, "The decomposition of peat." He is making very satisfactory progress toward a solution of the problem.

REPORT OF RESEARCH ASSOCIATE R. M. SNYDER

My Experiment Station work for the last year includes the following: I. The study of "Nitrobacter Soil Vaccine," a proprietary product for soil treatment, was conducted during the summer of 1921. Following preliminary bacteriological work, the vaccine was studied on four plats in the field. These plats comprised two different types of soil, and contained a variety of legumes and non-legumes. Two applications of the vaccine were made—the first when the plants were very small, and the second two weeks later. In both cases the solution applied to the plats was prepared strictly according to directions accompanying the material. The check strips were treated with a similar preparation from which the vaccine was omitted. Throughout the season the treated portions of the plats failed to respond more favorably than the untreated, and at the close of the season were no better than the untreated strips serving as checks. Data on relative yields and photographs of the plats were obtained and placed on file.

II. Studies on the bacterial decomposition of peat (Adams 2c) are being continued. In the fall of 1921 the crop on the peat cylinders used in this connection was harvested and threshed. Separate weighings of the seed, stems and leaves were made. Samples of soil from both the cropped and uncropped cylinders were taken and analyzed for total numbers of bacteria, actinomycetes, and molds, free nitrogen fixers, coli-aerogenes organisms, nitrifiers, ammonifiers, aerobic and anaerobic cellulose decomposers, sulfofiers, etc. Studies were also conducted on the ability of the flora from each cylinder to decompose raw rock phosphate. This work is being repeated on samples obtained at the time of planting in the spring of 1922, and it is planned to make similar determinations at intervals throughout the growing season. Physico-chemical analyses are being conducted on the drainage waters obtained from the cylinders. The amount of plant food rendered soluble in the peat bears a close relation to that removed by the crop and drainage water together. Work is being pursued in the laboratory on the influence of various organisms in pure culture on raw peat. When once the bacterial flora causing dissolution of insoluble plant food has been determined, the handling of peat soils may then be so modified as to facilitate the decomposition and dissolution of the unavailable plant food present.

[R. M. Snyder.]

Mr. Cooledge has been able to devote nearly all of his energy to research on the technical and applied phases of his major project. His method of determining the actual keeping quality of milk and dairy products is beginning to receive the recognition which it merits. He has devoted some time to guiding the research studies of graduate students.

REPORT OF RESEARCH ASSOCIATE L. H. COOLEDGE

During the past year I have continued work upon project Adams 3a, which has the following for its object:

(a) A study of methods in use at the present time for determining the bacteriological conditions of dairy products.

(b) An attempt to develop new methods where the old are found inadequate.

(c) A study of bacteriological problems relating to market milk by means of tests developed under (a).

In addition to the above outline of the project there has been approved during the past year and is under way in co-operation with Professor J. E. Burnett, of the Dairy Husbandry Department another phase. The object of this investigation is to determine the relation of various dairy practices to clean milk production and to find the practical dairy procedures which may be applied at the average dairy farm, with the best results from a sanitary standpoint.

During the past year the following bulletins covering some of my work have been published by this Station.

The colorimetric hydrogen-ion determination as a means of studying biological changes in dairy products. Technical Bulletin No. 52, November, 1921.

An experiment in improving the milk supply of a city milk plant. By L. H. Cooledge and O. T. Goodwin. Special Bulletin 112, November, 1921.

At the present time two phases of my problems are being studied in co-operation with members of the Dairy Department It is hoped that other phases may be taken up in a similar manner in order to bring a knowledge of bacteriology to bear on dairying to best advantage.

Work which is well under way includes the following problems:

The colorimetric hydrogen-ion determination as a means of locating faulty methods at city milk plants.

The pH test as a means of judging the suitability of milk for cheese making.

A study of the factors influencing the quality of milk during transportation.

The pH method as a means of paying for milk on a quality basis. (With Professor Goodwin of the Dairy Department).

The relation of discarding the fore milk to low bacterial counts in the production of a high grade market milk. (With Professor Burnett, of the Dairy Department.)

At the suggestion of Mr. Broughton, of the Bureau of Dairying, State Department of Agriculture, a study was made of the sanitary conditions surrounding the milk supply of Lansing and East Lansing and of Ypsilanti. Mr. Robbins, city milk inspector of Lansing, Dr. Pillsbury, Health Officer of Ypsilanti, and Mr. Friar, of the Bureau of Dairying, co-operated in this work. The object of the study was to see what could be accomplished in studying a city's milk supply in a limited time, the results to be presented to those interested for criticism and suggestion as a help in making future studies. These reports follow:

A STUDY OF THE MILK SUPPLY OF LANSING AND E. LANSING

L. H. Cooledge, Ed. J. Friar[1], and W. S. Robbins[2].

During the week beginning April 24th, a study was made of the milk supply of Lansing and East Lansing. All of the plants supplying milk were visited and scored as to sanitary conditions using the score cards for Sanitary Inspection of City Milk Plants recommended by the Dairy Division of the Bureau of Animal Industry, United States Department of Agriculture.

The average total score of the thirteen plants supplying Lansing was 42.2. This is based upon a perfect score of 100. The low average score is largely due to the fact that three of the plants were in such condition that it was necessary to give them a score of zero. One of these was at once shut out of the Lansing market by the Lansing inspector, and the other two were given a few days in which to get their plants in shape.

The tabulated scores of the Lansing plants are shown in Table No. 1.

TABLE NO. I.

Plant.	Sanitary Score.			Milk sold.
	Equipment.	Methods.	Total.	
Perfect score	40	60	100	
Milk Plant No. 1	31.5	36.5	67.0	Past.
Milk Plant No. 2	31.2	34.7	65.9	Past.
Milk Plant No. 3	28.0	26.7	64.7	Past.
Milk Plant No. 4	26.6	35.5	62.1	Raw.
Milk Plant No. 5	27.0	34.8	61.8	Raw.
Milk Plant No. 6	26.5	28.5	55.0	Raw.
Milk Plant No. 7	22.5	31.0	53.5	Raw.
Milk Plant No. 8	21.7	27.1	48.8	Raw.
Milk Plant No. 9	22.0	24.7	46.7	Past.
Milk Plant No. 10	21.0	22.0	43.0	Raw.
Milk Plant No. 11	0	0	0	Raw.
Milk Plant No. 12	0	0	0	Raw.
Milk Plant No. 13	0	0	0	Raw.
Average	19.8	23.9	43.7	

The score of the four milk plants selling in East Lansing will be found in Table No. II. A dealer whose plant was not visited is selling some milk at a restaurant. The high average score of these East Lansing dealers is due largely to the exceptional equipment and methods of the College raw and pasteurized milk plants.

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[1] Inspector, Bureau of Dairying, Michigan State Dept. of Agr.
[2] Sanitary Inspector, City of Lansing.

TABLE NO. II.

Plant.	Sanitary score.			Milk sold.
	Equipment.	Methods.	Total.	
Perfect score	40.0	60.0	100.0	
Milk Plant No. 101	35.5	53.0	88.5	Raw.
Milk Plant No. 102	37.5	48.7	86.2	Past.
Milk Plant No. 103	19.5	35.5	55.0	Raw.
Milk Plant No. 104	23.0	31.0	54.0	Raw.
Average	28.8	42.1	70.9	

The fact that one plant has a higher score than another does not necessarily prove that the one plant is delivering a safer grade of milk, but it does show that the one plant is better equipped to handle a safe product and is using methods which are more dependable than are those of the plant with the lower score.

To get an idea of the condition of the milk as it arrived at the city milk plant samples were taken upon arrival at Milk Plant No. 3 and at Milk Plant No. 1. These were tested for keeping quality by the pH method which grades milk according to the activity of the bacteria which are present rather than according to the numbers. These samples were taken upon a rainy day following a cold night and the samples are in much better condition than would have been the case had samples been taken on a warm day following a warm night. A score of 100 by this test is excellent and any samples scoring under 70 are very bad. Any sample scoring under 70 during weather as cold as when these samples were taken would be very bad indeed if the weather was warm.

The score of milk arriving at Milk Plant No. 3 follows:

	pH score.		pH score.
Dairy Farm No. 1	85	Dairy Farm No. 11	100
Dairy Farm No. 2	95	Dairy Farm No. 12	95
Dairy Farm No. 3	55	Dairy Farm No. 13	95
Dairy Farm No. 4	95	Dairy Farm No. 14	35
Dairy Farm No. 5	100	Dairy Farm No. 15	100
Dairy Farm No. 6	95	Dairy Farm No. 16	55
Dairy Farm No. 7	95	Dairy Farm No. 17	95
Dairy Farm No. 8	85	Dairy Farm No. 18	95
Dairy Farm No. 9	100	Dairy Farm No. 19	95
Dairy Farm No. 10	95		
Average score			87

The average pH score of 87 indicates that the milk as a whole arrived at the plant in excellent condition in spite of the very poor milk arriving from farms 3, 14 and 16. Attention should be given to these farms to locate the trouble and suggest means for overcoming it.

Enough samples were taken of milk arriving at Milk Plant No. 1 to get an idea of the condition of the milk arriving at that plant. The score of these samples follows:

Sample No.	pH score.	Sample No.	pH score.	Sample No.	pH score.
10	65	25	100	40	75
11	100	26	100	41	100
12	45	27	100	42	95
13	75	28	95	43	100
14	65	29	50	44	95
15	55	30	50	45	95
16	100	31	50	46	100
17	65	32	100	47	55
18	100	33	100	48	100
19	100	34	95	49	85
20	50	35	95	50	95
21	100	36	100	51	100
22	50	37	100	52	100
23	45	38	90	53	100
24	100	39	75		
Average...	..	..	..	..	85

The average score of 85 indicates that the milk as a whole was arriving at the plant in excellent condition in spite of the very poor milk arriving from the following farms: 10, 12, 14, 15, 17, 20, 22, 23, 30, 31, 32, 47.

Samples of milk taken from farmers supplying Milk Plant No. 102 at East Lansing scored as follows:

Sample No.	pH score.	Sample No.	pH score.
1	75	17	80
2	70	19	100
5	70	20	65
6	85	21	80
8	95	22	60
9	95	23	90
10	90	24	65
11	85	36	95
12	75	25	75
13	90	M. A. C.	90
14	85	50	90
16	95	51	65
Average....	..	..	80

The average score of 80 indicates that the milk as a whole is arriving at the plant in excellent condition. Poor milk is arriving from the farms of No. 20, 22, 51 and 54. The fact that the poor milk arriving at this plant is in better condition than the poor milk arriving at the other plants may be due to educational measures which have been carried on among the producers supplying this plant. At the present time all producers delivering milk with an average pH score of 75 or over are paid a bonus of 15 cents per hundred.

The milk as delivered to the consumers in Lansing had a pH score and fat test as tabulated in Table No. III.

TABLE NO. I.

Plant.	Sanitary score.			Milk sold.
	Equipment.	Methods.	Total.	
Perfect score	40	60	100	
Milk Plant No. 1	33.0	45.5	78.5	Raw, tuberculin test.
Milk Plant No. 2	25.5	34.0	59.5	Raw, tuberculin test.
Milk Plant No. 3	25.2	33.6	58.8	Raw, tuberculin test.
Milk Plant No. 4	26.5	32.0	58.5	Raw, tuberculin test.
Milk Plant No. 5	22.3	31.0	53.3	Pasturized
Milk Plant No. 6	21.0	28.0	49.0	Raw, tuberculin test.
Milk Plant No. 7	19.5	28.5	48.0	Raw, tuberculin test.
Milk Plant No. 8	20.0	25.5	45.5	Raw, tuberculin test.
Milk Plant No. 9	17.0	25.0	42.0	Raw, tuberculin test.
Milk Plant No. 10	12.0	28.5	40.5	Raw, tuberculin test.
Milk Plant No. 11	11.0	22.0	33.0	Raw, not tuber. test.
Milk Plant No. 12	13.9	18.5	32.4	Raw, tuberculin test.
Milk Plant No. 13	0	0	0	Raw, tuberculin test.
Milk Plant No. 14	0	0	0	Raw, not tuber. test.
Milk Plant No. 15	0	0	0	Raw, tuberculin test.
Average	16.4	23.5	40.0	

The fact that one plant has a higher score than another does not necessarily prove that the one plant is delivering a safer grade of milk, but it does show that the one plant is better equipped to handle a safe product and is using methods which are more dependable than are those of the plants with the lower score.

To get an idea of the condition of the milk as it arrived at the city milk plant, samples were taken upon arrival at Milk Plants No. 5 and No. 3. These were tested for keeping quality by the pH* method which grades milk according to the activity of the bacteria which are present rather than according to the numbers. These samples were taken on a moderate day as to temperature and the scores are better than they would probably have been upon a hot day. A score of 100 is excellent and any samples scoring under 70 are very bad. Any samples scoring under 70 during weather as mild as when these were taken would be very bad indeed if the weather was warmer.

The score of the milk arriving at Milk Plant No. 5 follows:

Sample No.	pH score.	Sample No.	pH score.	Sample No.	pH score.
1	50	6	90	11	100
2	50	7	90	12	80
3	70	8	85	13	95
4	90	9	90	14	55
5	90	10	50	..	..
Average...	..	..	..	..	77

The milk arriving at the Milk Plant No. 3 scored as follows:

	Sample No.	pH score.
	1	55
	2	50
	3	55
	4	55
	5	50
Average..........	..	53

The average score of milk arriving at the city Milk Plant No. 5 is satisfactory. The three samples with scores under 70 indicates a fault at some stage in handling at the farm. This milk arrived at the plant well cooled.

The milk arriving at Milk Plant No. 3 reached the plant with an average pH score of 53. There is a great opportunity for improvement here. The score of the milk which this plant was distributing was 55, which would indicate that the dealer was doing very well with the milk after he received it.

The milk as delivered to the consumer in Ypsilanti by the various dealers had a pH score as tabulated in Table No. II.

TABLE NO. II.

Milk plant.	pH score.	Milk plant.	pH score.
Milk Plant No. 9	53	Milk Plant No. 2	50
Milk Plant No. 12	85	Milk Plant No. 8	75
Milk Plant No. 4	80	Milk Plant No. 11	95
Milk Plant No. 1	100	Milk Plant No. 16	50
Milk Plant No. 6	55	Milk Plant No. 7	55
Milk Plant No. 3	55	Milk Plant No. 5	55
Average			67

The average pH score of 67 of milk as delivered in the city of Ypsilanti is hardly satisfactory, the majority of the samples having a score which indicates that the milk has been carelessly handled. The dealers delivering milk in the city do not use ice upon the bottles during delivery. Their excuse is that the milk is delivered during the night (from 3:00 A. M. to 8:00 A. M. in most cases) and that ice is therefore not needed. A number of the dealers drive several miles to town to deliver small amounts of milk. The smallest amount delivered was 12 quarts and the largest 1,900 quarts of pasteurized milk.

The unsatisfactory score of pasteurized milk sold by Dealer No. 5 suggested a progress pH* score at the different stages in the pasteurizing process in hopes of locating the trouble. This is shown as Table III.

Note—* A bulletin is being prepared at the Michigan Agricultural College showing how this is made.

TABLE NO. III.

	Time.	pH score.
1. Raw milk, pasteurizing tank	8:45	55
2. Heated to 145	9:37	60
3. Held 30 minutes	10:07	85
4. Cooled to 105 F	10:00	55
5. Top of cooler	11:00	55
6. Bottom of cooler at 52 F	11:00	55
7. From bottle		55
8. Pasteurized return		55

The fact that the milk had a pH score of only 85 after it had been 30 minutes at 145° indicated fault at this stage, as milk usually shows a better score after holding. An examination of the recording thermometer in use showed that five degrees higher temperature was being recorded than was being applied to the milk. This accounted for the low score after holding. The hour's delay after holding while the milk was being cooled in the pasteurizing vat and while preparations were being made for bottling allowed the pasteurized milk quite a time to stand at a growing temperature during which the score of the milk was lowered to 55. Due to a good brine cooling system, the milk after cooling and bottling maintained the score of 55 until delivered the next day.

Thinking the chief trouble with the pasteurizing process had been located it was decided to test the process the following day using an actual temperature of 145° F. and passing the held milk immediately over the brine cooler in order to do away with the milk standing at an incubation temperature so long. The results are shown in Table No. IV.

TABLE NO. IV.

	pH score.
1. Raw milk, pasteurizing tank	45
2. Heated to 145 F	55
3. Milk held at 145 F. for 30 minutes	100
4. Immediately over cooler to bottle	100

The above table shows that the trouble with the pasteurizing process was as indicated in Table No. III and easily remedied.

Unfortunately this plant has such an inadequate water supply that it isn't practical to treat the milk as shown in Table IV. The brine cooler and the spray vat cooler cannot be operated simultaneously for lack of water. However, this plant is about to move into a new specially constructed building and this difficulty will be ended.

Four thousand one hundred twenty quarts of milk sold in Ypsilanti by 15 dealers is from 37 farms and amounts to a per capita consumption of about 0.9 pints. Approximately 46 per cent of this is pasteurized by the one pasteurizing plant.

The writers suggest that in the future it be made more difficult for those desiring to sell milk in the city to obtain a license. It would be an easy matter to make those desiring to sell milk in the city come up to requirements as to equipment and methods. It is very difficult to bring about improvement in plants now existing.

Some arrangement should be made for laboratory examination of samples.

Perhaps arrangements could be made with the bacteriologist doing the work for the neighboring city of Ann Arbor.

We suggest that all milk dealers selling in the city be required to have steam in their plant, and that some of the poorer plants be gradually eiminated.

We would also suggest that the indiscriminate use of the term "Grade A" be forbidden. A case was found where this term was applied to milk of doubtful quality. [L. H. Cooledge.]

Mr. Huddleson has made progress on his project, Adams 3b, probably aided by the fact that he is able to devote his undivided attention to his investigations. We have a considerable investment in the equipment and experimental animals and it would be in the interest of economy to provide more men to make greater use of these facilities with the object of bringing results more quickly and more far reaching in their scope.

REPORT OF RESEARCH ASSOCIATE I. F. HUDDLESON

During the past year my time has been devoted entirely to the problem in bovine infectious abortion.

The following problems have been reported on during the past year:

The Susceptibility of Swine to Infectious Abortion, *Bact. Abortus* (Bang). *Vide*, Quarterly Bulletin, Michigan Agricultural Experiment Station, November, 1921, p. 43.

The Comparative Pathogenicity of Several Strains of *Bact. Abortus* (Bang). Technical Bulletin No. 55, Michigan Agricultural Experiment Station, 1922.

During the past year an attempt has been made to extend the immunization studies into several badly infected herds in Michigan. The treatment, when possible, was carried out under my personal supervision. Up to the present time (June, 1922,) 23 herds representing 360 head of cattle have received the vaccine treatment. Sufficient time has not yet elapsed to permit of a report on the results of the treatment.

We have in the experimental herd at the present time 33 heifers and cows, and 2 bulls, of which 16 cows belong to the Michigan State Department of Agriculture. These animals were obtained through the kindness of Mr. H. H. Halladay, then Commissioner of Agriculture, from the Coldwater State School.

We now have at the experimental barn 10 virgin sows and 1 boar which are being employed in studying porcine abortion.

The following problems are now being studied:

1. Diagnosis of bovine infectious abortion.
    (a) by means of serologic tests.
    (b) by means of allergic reactions.
2. The persistence of *Bact. abortus* in the tissues of an infected animal.
3. Immunization.—Under this general heading come the following problems:
    (a) The duration of the immunity.

(b) Do the organisms contained in the vaccine persist in the tissues of the animal body and if so how long?
(c) What effect does the vaccine treatment have on an existing carrier state in the animal?
(d) When is the most favorable time to administer the treatment (non-pregnant or pregnant)?
(e) Does the treatment have any effect upon the health of the offspring?

4. What are the factors involved in the premature expulsion of the fetus, due to *Bact. abortus* (Bang)?

5. Does the organism lie dormant in heifers which were infected at birth and invade the uterus after conception?

6. A rapid method for differentiating between virulent and non-virulent strains of *Bact. abortus.*

7. Swine Abortion.

There were received during the year 521 samples of blood (bovine) for diagnosis of infectious abortion, of which 200, or 37.6 per cent, were positive and the remainder negative.

There were also received 10 samples of blood from swine for diagnosis of porcine abortion (*Bact. abortus*) of which 5, or 50 per cent, were positive and the remainder negative. [I. F. Huddleson.]

Dr. Stafseth took up his duties about a year ago immediately upon his return from a leave of absence in Norway and has pursued his studies with enthusiasm, vigor and skill. He is devoting one-third of his time to teaching and the remainder to the projects discussed below. For the good of the State in general and of poultry husbandry in particular he should have abundant assistance.

REPORT OF RESEARCH ASSOCIATE H. J. STAFSETH

The Experiment Station work carried out since my return to the College in the latter part of July, 1921, may be divided into three classes, namely, research on poultry diseases, miscellaneous diagnostic laboratory examinations and field work.

I. Poultry Diseases.—Due to a general demand from the poultry breeders in the State chicken pox and bacillary white diarrhea have received special attention. A vaccine prepared according to the method employed by J. R. Beach, of the California Station, was tried on a flock of over 4,000 chickens, one-half of the flock being vaccinated and the other half left as control. The results were such as to discourage the use of this vaccine because of an increase of the internal form of the disease in the vaccinated flock shortly after the inoculation. It may be noted that the disease was quite prevalent in the flock at the time of vaccination and that the flocks showing the greatest increase in the diphtheritic form of the disease after the injection of vaccine were those which manifested symptoms of chicken pox most plainly prior to vaccination.

Thus as a curative agent the vaccine did not prove of any value. An effort to determine its prophylactic efficiency will be made during the next fall and winter.

Various medicinal agents such as trypan blue, powdered alum, potassium permanganate, argyrol, iodine and glycerine equal parts and aborno were tried out in the laboratory and on several large poultry farms. None of these seemed to possess any outstanding curative or preventative qualities. Further tests are necessary to definitely determine the value of these drugs and it is hoped that the work may be continued next year.

A number of experiments were started on bacillary white diarrhea for the purpose of determining the importance of the male as a carrier and spreader of the infection. Rather extensive studies have also been made of the various and biological tests for bacillary white diarrhea. The work on this disease is being prepared for publication.

Miscellaneous diagnostic work comes under two classes, namely, serological and tuberculin tests and autopsies.

The tuberculin test was run on 117 chickens, 4 were positive and 113 negative.

The Agglutination test for bacillary white diarrhea was run on 2,779 samples of sera; of which 273 were positive, 92 very weak or doubtful in reaction and 2,414 negative.

The following table shows the results of the 146 autopsies.

Disease.	Species.	Positive.	Negative.	Material unfit for examination.	No. of specimens. examined.
Bacillary white diarrhea	Avian	97	7	16	120
Botulism	Avian	10	3		13
Chicken cholera	Avian	1			1
Chicken pox	Avian	4			4
Coccidiosis	Avian	10			10
Depluming scabies	Avian	2			2
Glanders	Equine		1		1
Hemorrhagic septicemia	Bovine	1			1
Microbacillosis	Bovine	1			1
Non-infectious	Avian	31			31
Pneumonia	Avian	2			2
Pneumonia	Porcine	1			1
Rabbit Septicemia		2			2
Rabies	Bovine		1		1
Tuberculosis	Avian	9		1	10
Tuberculosis	Bovine		2		2
Total					202

II. A fatal disease of colts.— During the former half of the month of March 1922, a fatal disease occurred among suckling colts of this College. Three colts died less than 36 hours after being foaled and one, which was given 160 cc. of its dam's blood intravenously a few hours after birth, lived about eight days. A similar or identical disease occurred also in the latter part of April, 1917. At that time it was studied by Dr. E. T. Hallman and I. F. Huddleson, who described it as an acute interstitial nephritis of the equine. This disease was studied bacteriologically. An organism showing the same cultural and morphological characteristics as the one described by Mr. Huddleson in the Journal of the A. M. V. A., Vol. LI, N. S., Vol. 4, No. 5, pp.

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696-701, August, 1917, was found in the last three cases which were examined. Another organism was isolated from all four cases which resembled the former very closely both morphologically and culturally. The latter was slightly longer, grew better in subcultures and its colonies were not viscid when touched with the platinum loop. The colonies of both organisms were so much alike in appearance after 24 to 48 hours cultivation that this may account for the failure to find one of them in the first case examined. Another reason for this may be that from the first case only one-half of one of the kidneys was brought in for bacteriological examination. These two organisms were isolated from the kidneys, liver, spleen, blood, peritoneal fluid, and, in the case of the one colt living eight days, from one carpal and the hip joints. The blood of the dams of these colts was plated out and from two of them organisms were obtained which resembled the two bacteria mentioned above. Antigens were made of these two organisms and the blood sera of all the four mares were tested by the agglutination test. No successful agglutination was obtained with the antigen obtained from the former organism owing to its tendency to form a pseudo-agglutination. This was due to the tendency of this organism to form tenacious threads. With the second organism agglutination was obtained in dilutions of 1:50 and 1:100 with the sera of three mares.

Both organisms were tried for pathogenicity on guinea pigs and proved fatal in less than 16 hours. The organisms were recovered from the blood and peritoneal fluid. Post mortem changes were observed in the guinea pigs similar to those described by Mr. Huddleson. The pathogenicity decreased very rapidly upon artificial cultivation.

III. An acute septicemic disease of foxes was studied bacteriologically. A small micrococcus was isolated which proved fatal for guinea pigs. This organism together with two other cocci isolated from the same carcass were sent to a fox farm for animal inoculation. One of the inoculated animals died in four days with symptoms similar to those of the disease in question, but through some error in the records, it is not known which organism was injected into this fox. Lack of experimental animals terminated this work.

Since October, 1921, 11 trips have been made to various parts of the State for the purpose of helping poultry breeders in combating contagious diseases.

Professor Fabian has been able to devote only a small portion of his time and energy to research. Co-operating with a former student, Mr. R. H. Cromley, of Detroit, he has made a study of the influence of manufacturing operations upon the bacterial content of ice cream.

He has also had charge of water analysis in the absence of Professor Mallmann during the summer and they have collaborated in the following investigation:

A STUDY OF THE RELATIONSHIP BETWEEN THE OXYGEN CONSUMING POWER OF WATER AND ITS HYDROGEN-ION CONCENTRATION

F. W. Fabian and W. L. Mallmann.

Introduction.—In making a sanitary chemical analysis of water or of sewage, it is of value to know the oxygen consuming power of the sample, not that the oxygen consuming power is all important in itself but it is simply the evidence in determining certain sanitary conditions concerning the sample in question. The oxygen consuming power is defined as "the oxygen that the oxidizable compounds of sewage and water consume when treated in an acid solution with potassium permanganate." (1)

The significance of oxygen consumed from the chemical viewpoint is that it is a rough index of the amount of carbonaceous matter present. Its significance from the bacteriological viewpoint is that if organic matter is present it affords a better medium for the growth of bacteria. This may be desirable as in the case of sewage or undesirable as in the case of drinking water.

Plan of Work.—Our work had in mind a study of the relationship between hydrogen-ion concentration and oxygen consuming power together with a bacteriological study of the samples of water. The water was collected from wells in the vicinity of the College and East Lansing, analyzed when fresh and allowed to stand for several days or a week and analyzed daily. The analysis consisted of making a hydrogen-ion determination, testing for the oxygen consuming power, plating on plain agar and seeding in lactose fermentation tubes.

Methods.—The method used in determining the hydrogen-ion concentration is the colorometric method of Clark and Lubs (2). The method used for determining the oxygen consumed was the standard (recommended) method (pp. 26-27, Std. Methods, 1920). Suitable dilutions were made on standard plain agar (1) the plates incubated at 37°C. and counted at the end of 48 hours. Two 10 cc., one 1 cc. and one 0.1 cc. portions of water were placed in lactose fermentation tubes and incubated for 48 hours at 37°C. The above determinations were made on each sample when fresh and every day for four days and some cases (at the end of) the seventh day, in order to study the changes that took place.

Results.—A study of tables 1 to 12 indicates that the hydrogen-ion concentration of these samples of water decreases upon standing, the reaction of all samples being slightly alkaline. The oxygen consuming power increased then decreased as the water stood. The bacterial count, like the oxygen consuming power, first increased then decreased as the water stood, while in the case of gas production there was no constant relationship. The gas producing bacteria survived the period of experiment very well in most cases showing up well at the end of 4 or 7 days.

TABLE NO. I.

Sample 1—Well Water.

Days.	pH.	Oxygen consumed.	Count plain Agar.	Lactose fermentation per cent gas in			
				10 cc.	10 cc.	1 cc.	0.1 cc.
Fresh	7.4	0.62 Mg.	1	40	40		
1	7.4	0.95 Mg.	480	55	60		
2	7.4	0.94 Mg.	4,000				
3	8.2	0.60 Mg.	10,000				
4	8.4	0.48 Mg.	500		20		

TABLE NO. II.

Sample 2—Well Water.

Fresh	7.4	0.65 Mg.	2	40	35		
1	7.4	0.65 Mg.	120	60	20		
2	7.4	0.94 Mg.	584				
3	8.2	0.62 Mg.	640				
4	8.4	0.49 Mg.	10				
7	8.4	0.48 Mg.	460				

TABLE NO. III.

Sample 3—Well Water.

Fresh	7.4	0.65 Mg.	0	25	30		
1	7.4	0.71 Mg.	70	20	20		
2	7.4	0.77 Mg.	220	45			
3	7.8	0.70 Mg.	152	5	30		

TABLE NO. IV.

Sample 4—Well water.

Fresh	7.4	0.65 Mg.	1	30	5		
1	7.4	0.71 Mg.	73	50			
2	7.4	0.84 Mg.	69	10	40		
3	7.8	0.70 Mg.	26	20	60		
4	8.0	0.46 Mg.	0	50			
7	8.2	0.30 Mg.	Innumerable				

TABLE NO. V.

Sample 5—Well Water.

Fresh	7.4	0.65 Mg.	2	35	40		
1	7.4		830	5	5		
2	7.4	0.74 Mg.	4,300	30	15		
3	7.8	0.60 Mg.	180	10			
4	7.8	0.50 Mg.	10	10			

TABLE NO. VI.

Sample 6—Well Water.

Fresh	7.4	0.65 Mg.	2	15	10		
1	7.4		600	20	20		
2	7.4	0.76 Mg.	4,000	5	55		
3	7.8	0.62 Mg.	195	50	30		
4	7.8	0.48 Mg.	2	40	10		

TABLE NO. VII.

Sample 7—River Water.

Days.	pH.	Oxygen consumed.	Count plain Agar.	Lactose fermentation per cent gas in			
				10 cc.	10 cc.	1 cc.	0.1 cc.
Fresh	7.4	3.50 Mg.	6,500	20	20	30	20
1	7.4	3.60 Mg.	106,000	20	30	60	60
2	7.4	3.58 Mg.	100,000	55	55	50	35
3	7.8	3.22 Mg.	9,000	60	60	45	30
4	8.0	1.66 Mg.	22,000	80	60	50	50
7	8.2	....	1,400	70	60	40	....

TABLE NO. VIII.

Sample 8—River Water.

Fresh	7.4	3.50 Mg.	5,700	20	20	20	15
1	7.4	3.68 Mg.	94,800	30	25	60	60
2	7.4	3.44 Mg.	79,000	30	45	40	45
3	7.8	3.18 Mg.	6,300	40	50	30	30
4	8.0	1.68 Mg.	7,600	50	45	50	25
7	8.2	2.40 Mg.	900	40	40	....	....

TABLE NO. IX.

Sample 9—River Water.

Fresh	7.4	3.50 Mg.	4,300	20	20	20	30
1	7.4	4.06 Mg.	138,000	40	30	30	22
2	7.4	3.44 Mg.	1,500,000	10	30	30	50
3	7.6	2.95 Mg.	12,000	40	30	30	20
4	7.8	1.68 Mg.	3,400	40	40	40	30

TABLE NO. X.

Sample 10—River Water.

Fresh	7.4	3.50 Mg.	5,300	20	20	30	20
1	7.4	4.06 Mg.	150,000	40	40	30	30
2	7.4	3.40 Mg.	1,580,000	40	45	40	40
3	7.6	2.90 Mg.	7,000	40	40	30	15
4	7.8	1.69 Mg.	9,000	50	40	30	20

TABLE NO. XI.

Sample 11—River Water.

Fresh	7.4	3.50 Mg.	5,300	20	20	15	25
1	7.4	3.60 Mg.	145,000	30	30	35	30
2	7.4	3.60 Mg.	361,000	50	50	55	50
3	7.6	3.10 Mg.	24,000	50	50	45	20
4	7.8	1.74 Mg.	8,000	30	45	30	25
7	8.2	2.00 Mg.	[illegible]	....	....	....	....

TABLE NO. XII.

Sample 12—River Water.

Fresh	7.4	3.50 Mg.	4,600	20	30	20	20
1	7.4	3.60 Mg.	109,000	25	30	30	20
2	7.4	3.56 Mg.	133,000	60	60	65	45
3	7.6	3.04 Mg.	17,700	50	50	25	30
4	7.8	1.73 Mg.	1,900	35	50	....	....
7	8.2	2.10 Mg.	2,300	65	60	....	....

There seems to be no constant relationship between the hydrogen-ion concentration of water and its oxygen consuming power. In the case of the well water the hydrogen-ion concentration decreases more than in the river water although the latter has the greater oxygen consuming power. This can be explained upon the basis of the greater buffer action of the river water due to the larger amount of organic matter present. The decomposition of the materials present in the water tested had a tendency to make the water more alkaline. This also might be due to the driving off of CO_2 and the breaking down of acid salts into alkaline salts. Previous chemical examination of water from the same sources would indicate that this might be the case (3).

Conclusions.—1. The hydrogen-ion concentration of the water decreases upon standing.

2. The oxygen consuming power first increased then decreased.

3. The bacterial count first increased then decreased.

4. There seems to be no relationship between the hydrogen-ion concentration and the oxygen consuming power of water.

5. A relationship does seem to exist between the number of bacteria present and the oxygen consuming power of water.

References.—(1) Standard Methods of Water Analysis. (1920.)

(2) Clark and Lubs (1917), The Colorimetric determination of hydrogen-ion concentration of bacteriological culture media. Journal of Bacteriology, Vol. 11, Nos. 1, 2 and 3, pp. 1-34; pp. 109-136; pp. 191-236.

(3) Fabian and Ruehle (1920), Titration of Culture media. Report of Bacteriologist, Michigan Experiment Station. [F. W. Fabian and W. L. Mallmann.]

Professor Mallmann is not officially on the Station staff but he has for several years assumed certain responsibilities that properly rest on the Station workers.

REPORT OF MR. W. L. MALLMANN

Residents of the State have submitted 69 samples of water to this laboratory for examination during the past year. As in previous years, the greater share of these samples comes from rural districts. The percentage of samples condemned is less than in previous years, but this does not indicate necessarily an improvement in rural supplies. The number of samples examined is far too small to permit one to draw any such conclusions.

The College swimming pool has been examined almost daily, while in use. Seventy-three samples were examined during the school year. The bacterial counts have been somewhat higher during the past year, which I believe is due to the fact that the filter has not been working satisfactorily.

The method of disinfecting the water is also very unsatisfactory and should be supplanted by the use of liquid chlorine which, I believe, is a very effective method. The present method of dragging a cheese cloth bag of chlorinated lime through the water keeps the bacterial count down but is a very crude method of treatment.

WATER SAMPLES EXAMINED.

Source.	Reported as safe.	Reported as unsafe.	Reported as suspicious.	Total number of samples.
Deep wells (drilled)...	14	11	0	25
Driven wells...	7	7	1	15
Dug wells...	0	7	1	8
Lakes...	0	2	0	2
Streams...	0	2	0	2
Springs...	1	1	0	2
Cisterns...	0	2	0	2
Distilled water...	1	0	0	1
Unknown...	6	6	0	12
Totals	29	38	2	69

[W. L. Mallman.]

Mr. Frank S. Davenport, who came to us a year ago from the graduating class of the Massachusetts Agricultural College, has performed a very valuable service. He has assisted Dr. Snyder in his researches in soil bacteriology and has handled the greatly increased distribution of pure cultures of the nodule-forming bacteria in a most satisfactory manner.

MR. DAVENPORT SUBMITS THE FOLLOWING TABULATED REPORT:

DISTRIBUTION OF LEGUME CULTURES, 1921-1922.

	Garden bean.	Alfalfa.	Field bean.	Sweet clover.	Soy bean.	Garden pea.	Red clover.	Alsike.	Cow pea.	Field pea.	Vetch.	Total.
July.........	....	705	....	119	42	....	25	....	6	7	85	989
August......	....	2,361	....	318	1	....	45	9	......	......	602	3,336
September...	....	165	....	38	....	....	19	3	......	......	199	424
October.....	....	....	....	1	....	....		....	......	......	13	14
November...	....	1	....	4	....	....	....	....	......	......	....	5
December....	....	....	....	....	....	....	....	....	......	......	....	....
January.....	....	....	....	....	....	....	....	....	......	......	....	....
February....	....	3	....	2	....	1	1	....	......	......	1	8
March.......	....	1,803	....	706	11	11	553	52	......	22	12	3,170
April........	....	7,541	1	2,165	108	18	1,140	92	5	107	71	11,247
May........	7	3,155	105	725	1,815	8	243	38	52	37	28	6,213
June........	....	2,252	223	76	1,670	....	44	2	134	4	1	4,406
Totals.....	7	17,986	329	4,154	3,647	38	2,070	195	197	177	1,012	29,812

I feel much encouraged over the past year's results. For the first time since before the war we have enjoyed a year of uninterrupted, full-time, contented and productive effort to further the departmental program. A problem of great importance to us all is the development of research at this College and the relationship in the future of investigations in the Experiment Station to the investigative spirit and policy of the institution as a whole. The Division of Bacteriology is pleased and heartened by the evident purpose of President Friday to direct the solution of these problems in a spirit of modern, enlightened, educational statesmanship. We are grateful to you for your unceasing and increasing sympathy toward and support of our work.

Respectfully,
WARD GILTNER,
Bacteriologist.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE BOTANICAL SECTION.

Dean R. S. Shaw,
Michigan Agricultural College.
Dear Dean Shaw:

The work of the Botanical Section of the Experiment Station has been carried on this past year in the main with the same projects as in the preceding year.

The staff in charge of the different lines of work differed from that of the preceding year as follows: Dr. R. P. Hibbard was on leave of absence from September 1st to June 30th while occupying a fellowship at Johns Hopkins University. The Johnston fellowship, which was given Dr. Hibbard, is one that is offered only to men who are outstanding in their profession and is in reality an invitation to co-operate with Johns Hopkins University on given lines of research. Mr. C. W. Bennett was appointed part time research assistant in plant pathology beginning April 1st, being assigned to fruit disease investigations. By the terms of their appointment, Mr. Bennett becomes full-time research assistant beginning July 1st.

My personal work has been, so far as the Experiment Station is concerned, mainly of supervisory and advisory nature. I carried on some investigations, not yet completed, on the orange rust of raspberries and blackberries. The main results of the investigations in Plant Pathology are contained in the accompanying report by Dr. G. H. Coons, and in Plant Physiology in the accompanying report by Dr. R. P. Hibbard, both of which I wish incorporated as part of my report.

Respectfully,
E. A. BESSEY,
Professor of Botany, Botanist of the Experiment Station.

Dr. E. A. Bessey;
Dear Sir:

I submit herewith the annual summary of the work carried on in plant pathological investigations for the preceding year.

Adams 5 b.

This project calling for investigation of certain organisms (Sphaeropsidales) from the point of view of life relations and with reference to methods of identification by means of cultures and biological methods. has been continued and shows some progress.

Becoming interested in certain white forms which have developed in the cultures of *Phoma apiicola* made by Mr. Bennett, we have isolated these forms and have compared them with the single spore culture from which they have sprung. A study of these variations as they have appeared from time to time shows them to be attenuated forms without power of fruit body formation. This material is being prepared for publication, in collaboration with Mr. Bennett.

Similar work is being carried on with white strains of other fungi and these will be subjected to various tests for identification and comparison with the original pure cultures.

Work with animals has not advanced far beyond the position of last year. It can be definitely stated that the fungus cultures used definitely sensitize the laboratory animals. The reactions obtained are in part specific for the organism and in part general reactions to the group. The reactions of an anaphylactic type seem too coarse for identification work, and no success has been had with the hemolytic reactions. Further work will concern itself with the complement fixation reaction.

Hatch Fund Projects:

Under the Hatch fund projects various minor lines of work have been carried on. From this source is financed your work on cucumber and on ginseng diseases. The chief work carried on under the Hatch project is the collection of data for the Plant Disease Survey, which is annually summarized by the Office of Plant Disease Survey in Washington. Diagnosis of farmer's samples, determination of unknown and puzzling disease situations on minor crops, certain field investigations, all go to furnish the body of data used in preparation of the report to the central office.

State Fund Projects:

Celery Disease Investigations:

Celery work in co-operation with Mr. Ray Nelson has now progressed to the point where full attention can be given the development of resistant seed. The tests carried on at Kalamazoo last summer demonstrated without question that the strain of seed selected for disease resistance has this quality to a satisfactory degree. A row of this new strain subjected to the worst disease conditions in years, grew normally and developed a marketable crop of celery of good quality. In the row beside it, a certain pure-line Golden Self Blanching celery failed completely. Adjacent rows of other types of Golden Self Blanching were badly diseased. About 100 plants of this new variety were carried to seed production in the greenhouse, and this seed is being tested for general selection purposes. A report on the Yellows Disease of Celery is in preparation.

Potato Disease Investigations:

Investigation of the Black Leg Disease of Potato has been continued by J. E. Kotila. Work in the field at Chatham, Michigan, was badly hampered by the severe drought, and overwintering experiments gave no results because of the failure of the disease to develop in the fields at all. Inoculation work under conditions where plants were kept moist were successful. Study in the laboratory has taken into consideration the relation of the Black Leg organism to Bacillus carotovorus and interesting relations have been discovered. Attenuation of the Black Leg organism has also been accomplished.

In co-operation with the Department of Entomology, Mr. Kotila has carried on for some years study of the Potato Leaf Hopper. Results of this investigation have been prepared as a special bulletin and this is now in press.

Seed treatment work has been carried on at Chatham and at East Lansing. Especial attention has been given to the utilization of sulphur as a means of scab control. At present, the results have not been favorable to this chemical for use with calcareous soils.

Cereal Disease Investigations:

Investigation of various methods of control of Stinking Smut has been continued. The feasibility of certain dust treatments recommended by Australian workers has been extensively tested with winter wheat and it has been found that the dust treatments even with wheat that was excessively smutty have given sharp reduction of smut. The method when tested with oats has not given such good control of smut and is not recommended for this grain. Trials by county men have indicated poor results with oats. It would seem that the hull of oats interferes with complete dusting.

Bean Disease Investigations:

This work has been carried out by Mr. Nelson and has centered on investigations of the Mosaic disease of beans. The study so far has given basis for accurate diagnosis of Mosaic symptoms, and differentiation of the disease from other types of leaf mottling and curling. The disease has been transferred from diseased plants by agency of the aphid, Macrosiphon solanifolii. Account of these tests has been submitted for publication to Science.

Transportational Disease Investigations:

Studies of the causes of blemish-production in various fruits and vegetables have been carried on largely by Mr. Nelson. As a result of a series of studies upon grapefruit, orange, apple, cabbage, lettuce and potatoes, some light has been thrown on the nature of the breakdown which leads to blemish formation. In general it may be said that the breakdown is of the nature of asphyxiation and interesting results have been obtained by the use of various gases in storage chambers at various temperatures. A preliminary notice of this work has appeared and work so far completed will be presented in a series of articles. One of those dealing with breakdown in cabbage is now in preparation.

I would call your attention to the fact that the work is badly hampered for want of laboratory room and by lack of greenhouse space.

Respectfully submitted,
G. H. COONS,
Associate Botanist.

Professor E. A. Bessey,
Botany Department, M. A. C.
Dear Dr. Bessey:

I herewith submit the report of the work in Plant Physiology for the year ending June 30, 1922.

The work in Plant Physiology was somewhat reduced because of my absence from the College. By arrangement, the Adams 2d project was discontinued for the period of my leave and the services of my assistant, Mr. S. Gershberg, discontinued. As my work at Johns Hopkins rather unexpectedly turned out to be in the same general line that I have followed here, I assume it will not be out of place to append a brief memorandum to the present report.

(1) A study, conducted in the fall of 1921, of 15 culture solutions of Type I (1.00 atm.) with pure line Marquis wheat, seedling phase, using 5 plants in each of ten 2-quart jars for each solution, renewing all solutions every other day, determining the dry weight of the 750 plantlets individually and studying the results statistically. The results are the most valuable thus far obtained by the water culture method.

(2) A study identical with that above with the exception that the experiment was carried on early in the spring while the other was in the winter time. Both experiments were run in the greenhouse.

It was interesting to note that climatic conditions played an important part in determining the distribution of good and poor growth on the triangular diagram. For example, the peculiar injury called "magnesium injury" was marked in April and May but failed to appear in December. In December, a ratio of salts high in magnesium and low in both potassium and calcium proved to be the best for growth of seedlings, while in April a ratio of the same salts all in about equal quantities produced the best yields for seedlings. The general conclusions from this study follow:

1.Variability in plants frequently obscures any relation that may hold between the physiological values of the different solutions tested. This difficulty is to be overcome partly by using pure line seed, partly by improved methods of germination, and selection of original seedlings but probably mainly by employing larger numbers of seedlings with the same treatment. The best results have been obtained with pure line seeds, germinated in a special way, and with 50 plants for each solution.

The general conclusion follows that in view of the many kinds of conditions affecting the salt relations it is practically impossible for a single worker to secure results involving all the influential conditions in a known way. Co-operation of several workers with carefully controlled conditions is absolutely essential if definite knowledge is to be obtained.

It is suggested that the next great step in the study of salt nutrition of plants should be an attempt to provide at one or more places the necessary equipment for adequately controlling temperature, evaporation, the CO_2 content of the air, the oxygen and CO_2 content of the nutrient solution, the quality and intensity of the light, etc., besides the control already frequently used for salts, salt proportion and total concentration of the solution.

The project entitled "The Physiological Effect on Life Processes of Certain Plants Growing under Deficient or Improper Nutrition Conditions" was continued under the guidance of H. C. Young. In its present form it is directed towards a study of the effect of various fertilizer applications on the variation of sugar content in the sugar beet. In addition, a study is being made on the variation in sugar content as influenced by the unbalanced condition of the fertilizer salts. From studies in the laboratory it has broadened out to studies in the field. This present summer makes the second summer the project has been conducted in the field. Some very important results have been obtained, the details of which will be deferred until the present season's work is done. It is also wise to carry the work further since it is very desirable to get conclusive evidence over a series of years, if possible.

The experiment station work, besides that mentioned above, includes three projects carried on in co-operation with other organizations.

1. Co-operation with the Horticultural Department, M. A. C. The project under this co-operation is as follows: Fertilizer Experiments on Apple Trees. The object of this investigation is to study the influence of nitrogenous fertilizer under different conditions and the physiological changes resulting from these applications on the vegetative growth and fruit production of apple trees in their unfruitful condition.

The work was begun in 1920 and during my absence in 1921 was under the direction of H. C. Young. Many good data have been collected along the lines assigned to us, especially in (1) growth, (2) carbohydrate determination, (3) Nitrogen determination, (4) Carbohydrate production of the leaf, (5) leaf area and color, and (6) fruit setting.

2. In co-operation with the Ecological Society of America we are collecting soil temperature records. This season is the fourth season in this co-operation. During my absence, 1921-1922, the work was kept going as it took only a little time to change the record sheets on the instrument each week and only entailed a small financial outlay to get a year's supply of record sheets.

3. In co-operation with the National Research Council a study of the salt requirements of agricultural crops was undertaken late in the year 1918. Considerable data have been collected and sent to the committee in charge in the form of detailed reports. During the year 1921-1922, on account of my absence, co-operation was discontinued.

The work in the College included, as usual, graduate and under-graduate instruction. With my absence at Johns Hopkins University this instructional work fell to Mr. H. C. Young and the large classes he handled and the enthusiasm he instilled into the students certainly showed good returns for the year's work in plant physiology.

For your sympathy, co-operation, and willing assistance in all the varied interests of plant physiology, I wish to give you my many thanks.

Respectfully,

R. P. HIBBARD,
Plant Physiologist.

REPORT OF THE CHEMICAL SECTION.

Director R. S. Shaw,
College.
Dear Sir:

The work of the Chemical Section for the year ending June 30th is briefly summarized as follows:

The close of the last fiscal year marked the termination of our control of the fertilizer, feeding stuffs, and insecticide inspection laws, and the records pertaining thereto then in our possession were turned over to the State Department of Agriculture.

Much delay in the readjustment of the work of the Section was occasioned by the uncertainty concerning the tenure of office of three members of the staff who were not given contracts. Not until January 1st was the matter finally decided when Miss Bademer was given a contract for the remainder of the year. Miss Grettenberger was transferred to the Chemical Department of the College and Mr. O'Meara to the State Department of Agriculture.

This adjustment made it impossible to undertake any new lines of work as the projects then in progress occupied the time of the entire staff.

ADAMS FUND.

Project 2b.—"The Physico-Chemical aspects of soil acidity." The investigation of the role of adsorption in soil acidity has yielded very interesting results. A study of the nature of adsorption from solution by some of the simpler adsorbents has been made. Data obtained by the use of an activated ash-free charcoal indicate that many of the conflicting results of other investigators are erroneous and due to impurities, and it has been possible to reproduce and explain many of the contradictory statements made concerning the nature of adsorption by charcoal. One paper dealing with this phase of the work has been accepted for publication by the Journal of the American Chemical Society and another paper is being prepared.

Preliminary experiments with other and more complex adsorbents such as fuller's earth and kaolin, which more closely resemble soils, have yielded results that tend to greatly clarify our knowledge of the phenomenon known as soil acidity.

Project 2 ba.—"The organic nitrogenous compounds of peat soils." During the past year the work under this project has been confined to a study of the acid amide fraction of the nitrogen. At present an attempt is being made to determine quantitatively the dibasic amino acids in peat and correlate these quantities with the amounts of acid amide nitrogen.

Project 2 e.—"A study of the preparation and properties of pure vegetable proteins." It has been impossible to do any work on this project during the year, and, consequently, it will be discontinued.

HATCH FUND.

"A study of the availability of organic ammoniates". This work is very important at this time owing to the fact that more and more attention is being paid to the availabilty of organic ammoniates by both the fertilizer manufacturer and the consumer. Investigation has been actively pushed during the year. An article entitled, "Studies of the availability of Organic Nitrogenous Compounds—Part I", was published in the Journal of Industrial & Engineering Chemistry, Vol. 13, No. 10, p. 993, and two articles dealing with the chemistry of the laboratory method now commonly used for the determination of the relative value of commercial organic ammoniates are in preparation.

"The preparation of neutral solutions of Ammonium Citrate". Work on this project has been continued in collaboration with the Association of Official Agricultural Chemists. The methods of analyzing the solution under consideration have been studied and an article entitled, "The analysis of solutions of Ammonium Citrate", was published in the Journal of the above mentioned Association, Vol. 5, No. 4, and further data will be presented at the next meeting of the Association. As a result of this work Dr. Robinson was asked to serve as referee for the Association on the subject of the preparation of neutral ammonium citrate. This subject is of great interest to fertilizer manufacturers and control officials.

"The estimation of carbon-dioxide". This project has been closed, no further work on it being contemplated, except such collaborative work as may be requested by the A. O. A. C. which is investigating the methods devised in this laboratory for the analysis of baking powders.

"The Hydrogen-ion concentration of human feces". Owing to lack of help this project will be dropped. The results of the work already accomplished have been published in the Journal of Biological Chemistry, Vol. 52, No. 2, p. 445. It was found that the normal fecal reaction of apparently healthy men on mixed diets lies between pH 7.0 and 7.5, and that the causes influencing the reaction are physiological rather than biological.

MISCELLANEOUS.

Ninety-nine samples of a miscellaneous character were analyzed during the year. In addition, collaborative work for the Association of Official Agricultural Chemists has been done on crude fiber, determination of nitrogen in nitrates, sulfur in organic materials, phosphoric acid and insecticides.

At the last meeting of the said Association the writer was appointed referee on the subject, "Inorganic Plant Constituents", and considerable time has been spent on the development of methods for the determination of iron and aluminum, manganese, calcium and magnesium in the presence of a large excess of phosphoric acid such as obtains in the ash of seeds.

During the fall of 1921 more than 400 samples of sugar beets were tested for the Farm Crops Section and 60 samples were tested for the Botanical Section.

Urgent requests have been made upon us for co-operation on problems now being conducted by other sections of the Experiment Station, which we have been unable to grant owing to lack of help.

In conclusion, I desire to commend again the spirit of loyalty and devotion exhibited by all the members of the staff during a most unusual year and to express the hope that the importance of chemistry in relation to the many problems of agriculture will be more fully appreciated and that this section may function in the future to the full extent of its possibilities. For your advice and council during the year I wish to express my grateful appreciation.

Respectfully,
ANDREW J. PATTEN,
Chemist.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE SECTION OF ENTOMOLOGY.

Director R. S. Shaw,
East Lansing, Mich.
Dear Sir:

The present fiscal year has witnessed no change in the personnel of the Section of Entomology. It is believed that if it can be so arranged an assistant who would devote himself to the study of orchard and vineyard problems in the field could be employed with much profit. New problems in the control of fruit pests are constantly coming up, problems that must be passed up for the lack of some one to attack them. At present the whole field of entomology is covered by less than half of the time of each of two workers.

The work in parasitology has been greatly facilitated by the completion of the animal-house, supplying as it does housing accommodations for a few animals under observation and a small laboratory for making examinations of material.

Quite a bit of work has been done on Michigan's reindeer herd at the instance of the State Conservation Commission. Besides this, progress has been made in the survey of diseases of food-animals and the work in the control of human intestinal parasites has progressed favorably as well as considerable work on internal parasites of foxes.

During the year the European corn-borer has been constantly in mind and many trips have been made and many samples of suspected cases, sent in by mail, have been examined in order that no real case might be neglected. Thus far none of the real pests have been encountered.

The fall of 1921 witnessed the worst case of corn-ear worm, *Heliothis obsoleta,* ever seen by the writer. Great quantities of sweet corn and popcorn were destroyed and much field-corn as well. Of course nothing could be done for the season of 1921 after the attack was well under way, and therefore we confined our efforts to giving instructions aiming toward the avoidance of a similar loss during 1922. It is of course too early as yet to know how successful the campaign will be.

When the season was well advanced many ears of corn harboring a number of the larvae were sent in. These proved to be the fall army-worm, *Laphygma frugiperda,* and during the fall the corn ear-worm and the fall army-worm vied with each other in destroying the crop. Unfortunately the fall army-worm worked also in other crops notably in beans. Here the pods were eaten into and the contents of the seeds scooped out resulting in a characteristic injury which later was noticed by the seedsmen and which proved quite a mystery to them until the matter was explained.

The apple-seed chalcis, *Syntomaspis druparum,* appeared in limited numbers for the first time in our State. Its work shows as a depression and scar usually on the side of the apple, which on being bisected through the surface scar, shows a healed up path leading to the core. An examination of the seeds shows part or all of them to be scooped out leaving little more than a shell, some of these shells enclosing larvae or grubs. The grubs pass the winter in fallen apples, to come out in the spring for the purpose of laying their eggs in the small apples of the next season. This pest is most easily controlled by the destruction of all fallen apples before winter sets in.

The garden web-worm, *Loxostege similalis,* was more troublesome than usual in alfalfa, the damage was most serious in young seeding where it was possible to do very effective work by merely rolling the land. The roller crushes the larvae without seriously injuring the young plants.

Grasshoppers.—The grasshopper invasion has progressed according to schedule. The areas which have suffered the most and the longest are showing a marked improvement. The grasshoppers are dwindling and in the Lower Peninsula the number of blister-beetles is increasing. New areas are, however, becoming infested on the borders of those already infested as was to be expected. In the Upper Peninsula the progress has not been so great, largely because the land is less thickly settled and the invasion is not so old. Furthermore, the use of poisoned bait has not been so vigorously pursued. Nevertheless hair-snakes, *Gordiinae,* are plentiful and a teacupful of the large *Melanoplus femoratus* from this region yielded half a teacupful of the worms known as hair-snakes on being torn apart. It is to be expected that the blister-beetles will soon appear and make their presence felt in this northern region.

As noted in the report of last year one of the grape leafhoppers, *Typhlocytba tricinta* was exceedingly common in the grape belt. A strong effort was made to successfully combat this pest by means of sprays although the writer is convinced that permanent relief will be obtained only through the destruction of the winter quarters of the pest, viz. fallen leaves, rubbish and similar shelter of all sorts in the vicinity of the vineyards. However, it was clearly demonstrated that the leafhopper may be controlled although sometimes with difficulty by one or more sprays of Bordeaux and forty per cent nicotine sulphate, the first application to be made just before the hoppers get their wings. Success depends largely on the thoroughness and force of the application and on the care with which the under surface of each leaf is coated with the mixture.

The grape-berry moth received considerable attention at about the same time as the leafhopper. This insect has been steadily growing more serious in the grape belt for a number of years. The experience of the summer of 1921 would appear to indicate the superiority of Kedzie mixture and Bordeaux over everything else in the control of the pest, the number of applications being determined by the gravity of the attack but always there should be a spray about three or four days after bloom and another when the grapes are about the size of buck-shot and before they touch in the cluster, it being possible at that time to make the spray penetrate between the berries so that each berry receives a coat of poison on all sides.

Paradichlorobenzene has apparently come to stay. Its use in the control of the peach-borer has given us much gratification. Thus far no harm seems to have resulted from its use in this way and the destruction of the borers seems to have been almost complete. At any rate complete enough to make it a commercial success.

Our efforts toward getting the time for the most effective spray for the second brood of the codling moth seem to have been generally successful. It would be of great value to run a string of cages straight across one or two counties, from the lake shore inland in order to determine how far the influence of Lake Michigan extends and just to what extent the time of emergence and consequent hatching of the second brood of eggs is influenced by the lake. This will be done next year if it is financially possible.

For the first time in the experience of the writer, white ants actually injured corn in our State. An inquiry into the case revealed the fact that there were in the field a quantity of decaying stumps which harbored the termites and from which they attacked the corn.

The potato leafhopper which causes hopper-burn in potatoes was prevalent during 1921 and is now appearing to a more limited extent in 1922. We are recommending the use of Bordeaux. The addition of nicotine sulphate adds to its effectiveness but the use of the latter poison seems to be hardly warranted for use on potatoes owing to its cost, and in most cases the grower seems to be able to "get by" with the Bordeaux alone.

For several years now the writer has been experimenting with a new borer repellant directed primarily against the flat-head borer of apple. Thus far the results have been very gratifying and if the results of the present season do not prove contradictory we may hope to put out some advice of commercial importance in the near future.

Two new pests of fruit have appeared during the year, one the grape-blossom midge, *Contarinia johnsoni,* which destroys the grape while in the bud stage and which has baffled growers in the East for several years; the other the apple flea weevil, *Orchestes canus,* an insect apparently of lesser importance which eats small pits in the foliage of apple.

Another record of interest is the finding of a flea, hitherto found only as a rarity in Brazil, a flea inhabiting the rat, and therefore, properly under suspicion as a possible carrier of disease. The few specimens received came from Detroit and are known as *Pulex brazilensis.*

At no time in the past has the cockscomb gall of elm, *Colopha ulmicola* been so prevalent. Every day for months has brought in samples of this aphis and of its work. Furthermore aphids of all sorts are plentiful. The cool damp weeks of early spring being unfavorable to the development of aphid parasites. Canning peas have suffered severely. The pea aphis, *Macrosiphum pisi,* developing on clover, early in the season and migrating to the peas during July in swarms. Dusting experiments have proven that it is possible to destroy the lice but whether this can be done at a profit in the generality of cases is still open to grave doubt. The development of a new killing agent for plant-lice, a cheaper killing agent that can be used freely against plant-lice on potatoes, peas and many other field crops, is still greatly to be desired. Nicotine is effective but expensive and its use does not seem to be warranted in the protection of some of these crops unless, of course, the price of the product can be raised to meet the extra expense.

During the late winter the Section of Entomology entered into co-operation with the Section of Farm Management for the purpose of determining the actual cost of production and of other details in the business management of apiaries. The work is progressing finely and is greatly appreciated by the beekeepers of the State as well as by leaders in the business of beekeeping in other states.

Respectfully submitted,
R. H. PETTIT,
Entomologist.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE SECTION OF FARM CROPS.

Director R. S. Shaw,
Michigan Agricultural College.
Dear Director Shaw:

I herewith present the annual report of the Farm Crops Section for the fiscal year ending June 30, 1922. Considerable increase has been made in the number of projects handled, and in the duties and responsibilities of the Section in the period covered.

The importance of Professor Spragg's work is demonstrated by the widespread use throughout this State of the Rosen Rye, Red Rock wheat, Wolverine oats, Robust beans, Mich-2-Row and Black Barbless barley. The Rosen rye, Wolverine oats, Red Rock wheat and Robust beans have spread to other states and are proving of great value over a wide territory of climatic and soil conditions similar to those of Michigan.

The Hardigan alfalfa, recently released by Professor Spragg, shows great promises as a seed and forage yielding variety in Michigan. With the increase of this variety under suitable conditions, it may be possible to establish an alfalfa seed production industry in Michigan, which should aid greatly in placing this crop on a more stable basis. Mr. Olaf Nelson of Aloha, Michigan, who is working in co-operation with the Farm Crops Department, secured six and one-half bushels of cleaned seed from one acre of Hardigan. He has greatly extended his plantings and in addition many members of the Michigan Crop Improvement Association are growing Hardigan under inspection for seed. Approximately one hundred and forty acres are now planted to Hardigan for seed increase under inspection.

Potato breeding work has been instituted and new and improved varieties can be expected within a few years. The breeding work with Rosen rye is apparently bringing out an improvement over the original release. The wheat breeding work has been brought to the point of the increase of several strains of great promise from the standpoint of winter-hardiness and milling quality, although it is doubtful whether any of them are superior in yield to the Red Rock. These strains must be further increased and tested in the State before final results can be secured. Five acres of the Improved Robust bean were planted on the Station Farm in 1922. This is a selection from the Robust originally sent out. It is apparently a higher yielder and is equally resistant to the Mosaic disease.

A yield test series of ryes was planted last fall. This has been needed for a number of years. When the Rosen rye was originally distributed in 1912 the tests on the Station plats showed that it was yielding about twice as much as the ryes generally in use. Because of its superior yield and quality it would have entirely replaced all original ryes, had it not been that it, being an open fertile crop, was somewhat intercrossed with inferior rye varieties in earlier years. Five years passed before the Michigan Crop Improvement Association instituted field and grain inspection in 1917, selecting only five per cent of the Rosen rye to continue as certified Rosen. The different growers, through selection from their strains of Rosen, have produced different strains but nothing was known regarding the relative yielding powers of these strains. Also, during the last decade, considerable rye breeding has been done by other experiment stations. As Rosen rye is now sold to buyers in nearly every rye growing state, it was advisable for the Michigan Station to make a collection of the ryes recommended by other stations and conduct a complete varietal test.

Professor F. A. Spragg has been assisted in the plant breeding work by E. E. Down, Research Assistant and H. M. Brown, Graduate Assistant.

The alfalfa project, including the testing of forty-eight varieties from leading commercial sources, which supply Michigan home-grown seed, was a great help in safely guiding recommendations made during the progress of the alfalfa campaigns carried on during the year. These tests showed markedly the advantage of Grimm, Cossack, and common alfalfa from the northwest over varieties from southern states, or seed secured from the Mediterranean countries and South America. The Grimm and Cossack were better adapted and hardier than the common alfalfa from the northwest. The Hardigan alfalfa, used as a check, was a leader in the test. Extensive time and rate of planting experiments with alfalfa were planted in the spring. Professor C. R. Megee directed these tests.

A state-wide alfalfa campaign was carried on throughout the year. It is estimated that over 275,000 acres of new alfalfa seedings were planted this spring, carrying the total acreage to over 500,000 acres for the State. The spring season was very favorable and alfalfa seedings were unusually successful. Michigan grown alfalfa seed was an important factor in increasing the acreage, over 150,000 pounds having been planted. The summer season of 1921 was exceptionally dry and warm, the widespread attention was called at that time to the unusually good conditions for a seed harvest. This is the first year that Michigan grown alfalfa seed was of importance.

The clover work involved comparative tests of native grown and imported clover seed. Michigan grown clover seed and seed from northern states was shown to be much more valuable for Michigan than Italian red clover or clover seed from southern states. Without doubt, these latter strains gave much less yield due to lack of hardihood and to great injury from anthrocnose.

Arrangements have been consummated to co-operate with the United States Department of Agriculture, Bureau of Plant Industry, in extensive investigations of red, alsike and sweet clover, covering the next three years, involving seed and forage production and adaptation investigations. A co-operator from the Bureau of Plant Industry will be associated with the department en-residence, during the period of investigation. Professor C. R. Megee of the Crops Department has had direct charge of the clover investigational work.

The first large increases of improved corn from the ear-row breeding work of the past two years were made during the spring. Twenty bushels of improved Duncan, thirty of Golden Glow and eighteen of M. A. C. Yellow Dent were placed with the growers of the Michigan Crop Improvement Association for increase under inspection. Much is expected of these high yielding varieties when sufficiently increased for widespread distribution. The ear-row work has been conducted on an extensive scale and occupies about fourteen acres.

Corn varietal test work is being carried on in its fourth year. Last fall's results showed conclusively that northern grown varieties, grown for two or more seasons in Kansas, lost their hardiness and hence the practice of growing varieties adapted to Michigan for seed purposes in states to the south of us is unsound.

The increases of selected ears of sweet corn, resulting from plantings of 1920 and 1921, in co-operation with a large Michigan canning company, were planted in the spring of 1922.

The frost resistant selection work shows promise of bringing out hardier varieties which can be planted much earlier in the spring. The first considerable increase is being made this year. Ear-row selection work with Australian hulless popcorn has been initiated. Mr. J. R. Duncan has been in charge of these experiments. In addition to the ear-row work, Professor Spragg and Mr. Duncan are conducting selfing work in the increase fields of improved varieties.

With the assignment of the potato crop to the Farm Crops Section, the experimental work with potatoes was greatly extended. The plant breeding work with potatoes occupies approximately four acres of ground. It is now in its second year. Professor F. A. Spragg and Assistant Professor C. E. Cormany are handling this work. Time of planting experiments with both late and early varieties and rate of planting experiments have been started under the direction of Mr. Cormany.

The extensive experimental work at Chatham with potatoes is now in its fourth year. Varietal testing, selection work and cultural experiments are being continued. With the transfer of Mr. G. W. Putnam from the Upper Peninsula Sub-station to the position of Assistant Professor and Extension Specialist in this department, Mr. H. R. Pettigrove was appointed as Farm Crops Experimenter, delegated to the Upper Peninsula Sub-station.

Mr. J. W. Weston and Mr. H. C. Moore, Extension Potato Specialists, are actively aiding in carrying on co-operative potato experiments at the Graham Sub-station, Grand Rapids, at the new Mancelona Experiment Farm and other points in the State. Particular effort will be made to develop improved varieties of potatoes and to perfect cultural methods.

The rye selection and increase work on the South Manitou Island is in its third year. The entire Island is planted to selected Rosen rye, and the Island is furnishing an excellent source of high yielding seed. During the past two years South Manitou samples have won the first prize in the rye class at the International Grain and Hay Show at Chicago.

Mr. D. F. Rainey, in charge of co-operative field experiments, reports the planting of eighteen tests of alfalfa varieties, four wheat variety tests, eight oat varietal tests, and four barley tests.

The local experiments with alfalfa varieties under Mr. Rainey greatly aided, at the recent state-wide alfalfa campaigns, in calling attention locally to northern grown seed, particularly the Grimm, and also the value of home-grown Michigan seed from hardy varieties.

The crops work at the Upper Peninsula Sub-station is now on a sound basis. Mr. G. W. Putnam during his three years of service did work of much value, calling attention to crop varieties of proper adaptation, in establishing planting dates by careful experiments, and in introducing the sunflower crop as a successful silage crop. Mr. H. R. Pettigrove, appointed Assistant in Crops, April 1st, is carrying on the major crop experiments at the Upper Peninsula initiated by Mr. Putnam, with the addition of sugar beet seed production experiments and more extensive potato work.

The work with sugar beets under Mr. Down includes comparative tests of seed from leading European sources and home-grown seed, time and rate of planting experiments with beets, and seed production investigations.

Extensive fibre flax breeding work has been conducted by Mr. R. L. Davis of the Bureau of Plant Industry of the United States Department of Agriculture. Mr. Davis' work occupies five and one-half acres of land and gives promise of producing excellent seed strains for Michigan's fibre flax industry.

Members of the Section particularly appreciate the action of the State Board of Agriculture in making possible the appointment of four additional graduate assistants. Without doubt many new research problems can be accomplished with this additional help.

Mr. George Getman, Field Foreman, has earned the appreciation of all members of the Section, engaged in field experimental work, by his excellent service in accomplishing field operations.

The number of inquiries received from farmers by mail relating to crops questions has greatly increased. Eleven thousand, four hundred and eighty first-class letters were written by Experiment Station and College workers in the Farm Crops Department and eight thousand, four hundred and seventy-five first-class letters by Extension men in Crops, or a total of nineteen thousand, nine hundred and sixty-one letters in answer to crops inquiries. In addition a large number of inquiries were answered by appropriate bulletins or circulars.

I particularly appreciate your assistance as Director in making possible the advancement of projects of this Section, through the granting of additional financial resources and land for experimental purposes.

Yours respectfully,
J. F. COX,
Professor of Farm Crops.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE FARM MANAGEMENT SECTION.

Dean R. S. Shaw,
College.

Dear Dean Shaw:

I wish to make the following report for the work of the Farm Management Section of the Experiment Station for the year ending June 30, 1922, which work has been under the immediate charge of Mr. F. T. Riddell. In approaching a discussion of this work it is well to state briefly the farm management problem.

The 196,000 farmers of Michigan preside over as many independent business units, and each one is dependent for his success:

1. Not only upon his health, thrift, and energy, but
2. Upon knowing which is the most profitable type of farming for his section.
3. Upon knowing which is the most profitable combination of crops, and live stock under the limitation of his capital, and
4. Upon having usable data to guide him in investment choices.

As each farm business is a growing organism, changing from year to year, and as each farm manager is always approaching a set of experiences new to him, the business experiences of other farmers farther advanced up the "agricultural ladder" are of inestimable value as a guide. The fact then is that a series of progressing conditions are encountered as a farmer moves up the "agricultural ladder," whether he starts as a farm laborer, a poorly equipped tenant, the owner of a small encumbered farm or even should he be so fortunate as to inherit a well equipped farm free from debt.

There are three ways of moving along this unfamiliar road:

1. The manager may move without a guide excepting only such guidance as comes from his limited opportunity of observation. A percentage of such farmers will fall into expanding lines of farming and prosper, those fortunate by inheritance will be able to maintain themselves, and still others by sacrificing their standard of living will pay out on a modest farm home, while many will fail.
2. The manager may do his own experimenting and investigating. While this is the method pursued by established business institutions, it is too costly for so small a business unit as a farm and more particularly for a beginning farmer. This is attempted, however, by an occasional farmer, who, because of the expense involved, usually fails to prosper, and thus brings "scientific farming" into disrepute in his community.
3. The experimenting may be carried on at the Agricultural College and may be extended to farmers through the public school system, the extension service, and the agricultural

press. This is the recognized policy of the older departments of the College and it is the policy entered upon by the Department of Farm Management when organized a little over a year ago. In the pursuance of this policy the Department set out to collect data:

1. Upon the relative profitableness of the various types of farming in Michigan.
2. Upon the relative profitableness of the various combinations of crops and live stock within each type.
3. Upon investment units and the relative returns from investment units and the order of investment as the manager progresses in a financial way.

As the department was new and practically no data was at hand a large experiment station force was necessary, and such a force was most generously provided by the Board of Agriculture. Two accounting routes were taken over from the Dairy Department and two other routes were established. These routes as operated during the year were as follows:

Type of farming.	County in which located.	Man in charge.	Number of farm records completed.
Dairy	Wayne, Monroe	R. E. Post	24
General	Jackson, Shiawassee	O. E. Dunckel	23
Feeder	Lenawee	H. N. Chapel	24
Potato	Montcalm, Antrim, Emmet	G. E. Culver	20
Total			91

The dairy route in Wayne county was discontinued at the end of the accounting year (April 30, 1922) and a new route started on April 1, 1922 in the dairy and fruit section of Oceana county, with Mr. D. T. Musselman in charge.

On these routes each farmer is visited once a month, the route man arriving in the early afternoon and staying on the farm until the middle of the next day. At chore time, feed and milk are weighed and the farmer is timed as he proceeds with the chores to determine the amount of time consumed in caring for each kind of live stock. During the day the financial records for the month are checked and posted. Inventories are also taken at the beginning and at the end of the year.

To make the taking of data most effective, monthly conferences of route men were held at the College. At these conferences the problems of the farm manager were discussed to the end that the data secured would be in a form directly usable by farmers and also for classroom teaching.

In making these studies the work has been carried on under the following projects.

A study of Farm Management, Farm Accounting and Farm Practices on dairy farms in Wayne and Monroe counties in co-operation with Dairy Department.

A study of Farm Management, Farm Accounting and Farm Practices on farms where their major business is feeding beef cattle and sheep in cooperation with the Animal Husbandry Department.

A study of Farm Management, Farm Accounting and Farm Practices on farms where major business is potato farming.

A study of Farm Management, Farm Accounting and Farm Practices on farms practicing general farming.

In the following projects the department is co-operating with other departments at their request.

With Farm Mechanics:

1. Farm Tractor Investigations.
2. Drainage Investigation.

With Entomology:

1. Costs of Producing Honey.

The department has also co-operated with the Home Economics Extension in a study of comparative cost of living in the city and country.

PUBLICATIONS.

During the year the Farm Management Department has published the following articles in the Quarterly bulletin:

Feb. 1922.	1921 Potato Costs	F. T. Riddell
	Direct Costs on Horses	H. M. Eliot
Nov. 1921.	Opportune Time to Sell Farm Crops	H. B. Killough
	Dairy Cattle Costs	F. T. Riddell W. J. Kurtz
May 1922.	Analysis of Dairy Records	F. T. Riddell S. J. Brownell
	Bordeaux Use with Profits on Potatoes	C. E. Culver
	The Tractor as a Means of Farm Power	D. T. Musselman E. C. Sauve
	Accounting Records of Beekeepers	R. Kelty F. T. Riddell

BULLETIN MANUSCRIPT.

The manuscript of a bulletin on the Farm Tractor has been prepared by this department and the Farm Mechanics Department co-operating. The data for this bulletin was gathered partly by the route men from tractors owned by the route farmers, but mostly by surveys conducted by route men, Mr. Riddell, Mr. H. M. Eliot, and Mr. D. T. Musselman. Mr. D. T. Musselman of the Farm Management Department spent his entire time from January 1, to April 1, in gathering data and preparing the manuscript.

The manuscript has been approved by a committee and is now in the hands of the Director of the Station. The tractor bulletin is the first fruit of the study of "units in farm investment," which study will ultimately cover all the units in farm investment and farm organization.

The following data is taken from the tractor bulletin:

The table below shows the average number of horses released on different sizes of farms up to 320 acres of cultivated land, beyond which there are too few farms reported to give a fair average.

HORSES USED BEFORE AND AFTER PURCHASE OF TRACTOR 322 TRACTOR FARMS.

Size of farm in acres cultivated.	Number farms.	Average horses.		Average number reduced.
		Before purchase tractor.	After purchase tractor.	
80 acres or less	36	4.16	2.60	1.56
81–120 acres	101	4.64	3.35	1.29
121–160 acres	82	5.63	3.96	1.67
161–200 acres	41	6.43	4.93	1.50
201–240 acres	22	6.50	4.60	1.90
241–280 acres	11	8.00	5.72	2.28
281–320 acres	8	9.86	6.71	3.15
321–400 acres	6	9.17	6.17	3.00
401–440 acres	2	10.00	6.00	4.00
Over 440 acres	8	14.00	13.62	.38

The table below shows the possibility of the farmer adding to his crop acreage with the purchase of a tractor. In cases where the farmer is not operating to capacity the tractor should enable him to add a considerable acreage to the amount he is now working.

Group 1 consisted of 16 farms with an average crop acreage of 141.3 before tractor was purchased, while group 2 comprised 86 farms averaging 174.7 acres. The farmers of group 1, changed their power factors practically the same as group 2, and in addition increased their crop acreage an average of 60.1. The data would indicate that where farmers are not operating up to capacity they might reasonably expect to operate more land with the purchase of a tractor.

THE POSSIBILITY OF INCREASING CROP ACREAGE WITH TRACTOR PURCHASE.

Group.	Number of farms.	Acreage increased.	Horse reduction.	Month's man labor reduction.	Size farms in acres.
1	16	60.1	1.6	3.3	201.4
2	86	0.0	1.9	3.3	174.7

The following data were secured on the rate of doing some of the farm operations.

RATE OF DOING WORK WITH TRACTOR 86 FARMS.

Operation.	2 bottoms.		3 bottoms.	
	Number farms.	Rate acres per 10 hr. day.	Number farms.	Rate acres per 10 hr. day.
Plowing	65	5.51	21	7.07
Discing	65	17.59	21	23.15
Harrowing	65	24.92	21	24.58
Cultipacking	65	23.71	21	25.49
Binding grain	65	16.20	13	15.00

The tractor operator was asked his repair costs for the last year only. These were grouped into systems. Two hundred forty-eight tractor operators answered the question on cost of repairs. The following table shows the increase in the cost of repairs for the first four years. It will be seen that the cost of repairs tends to increase each year. The last column shows the number of hours the operator spent on repair work. The costs included the expert labor for the different years.

REPAIR COSTS ON TRACTORS FOR DIFFERENT YEARS.

Year.	Number reporting.	Cost of repairs.	Increase in cost.	Hours operator's labor.
1	111	$19 86	....	4.5
2	61	36 16	$16 30	10.04
3	49	47 50	11 34	8.9
4	27	54 63	7 13	12.9

FUEL AND GREASE COSTS PER DAY.

Fuel used.	Gallons.	Price.	Cost.	Amount grease pounds.	Price.	Cost.	Total cost per 10-hr. day.
Gasolene	13.9	$0 25	$3 48	.6	$0 19	$0 11	$3 59
Kerosene	17.5	.126	2 21	.6	.19	11	2.32

The following table is a summary of the cost of keeping 245 horses on 46 farms in Jackson, Shiawassee and Lenawee counties for the year ending March 31, 1922. The prices are figured at local market price each month.

AVERAGE DIRECT COST ON 1 HORSE FOR 1 YEAR—1921-1922.

Item.	Quantity.	Value.
Oats	1,385 lbs.	$13 74
Corn	848 lbs.	7 63
Barley, bran, etc	52 lbs.	28
Hay	6,615 lbs.	30 86
Straw, silage, stover	987 lbs.	1 80
Pasture	7.4 wks.	2 80
Bedding	1,348 lbs.	2 91
Net depreciation on horses	....	10 69
Depreciation on equipment	....	2 92
Miscellaneous costs	....	3 08
Total direct costs	....	$76 71
Manure	....	12 00
Cost to keep a horse	....	$64 71

The following are average money yield, direct costs, and net returns on 254 cows on 23 farms in Jackson and Shiawassee counties for the twelve months ending March 31, 1922. The data was gathered by O. E. Dunckel on the general farming route:

Average for 1 cow for 1 year, year ending April 1, 1922.

ENTERPRISE YIELDS.

Items	Amount	Value
Milk sold	1139 lbs.	$ 27.03
Butter fat sold	185 lbs.	87.90
Milk used in home	202 lbs.	4.00
Milk fed to live stock (skim)	343 lbs.	14.56
Milk fed to live stock (whole)	3415 lbs.	
Butter used in home	6.4 lbs.	2.63
Meat used in home		.25
Miscellaneous receipts		1.32
Manure	8.4 tons	16.76
Total Milk Production	6247 lbs.	
Money Yield Per Cow		$154.45

DIRECT COSTS.

Items	Amount	Value
Corn	492 lbs.	$ 5.23
Oats	687 lbs.	8.03
Wheat	8 lbs	.13
Rye	4 lbs.	.04
Barley	87 lbs.	.95
Middlings	5 lbs.	.08
Bran	126 lbs.	1.60
Oil Meal	69 lbs.	1.84
Cotton Seed Meal	142 lbs.	3.32
Miscellaneous Dairy Feed	47 lbs.	.90
Distiller grain	.5 lbs.	.01
Corn gluten	19 lbs.	.28
Beans	.5 lbs.	.01
Beets	9 lbs.	.02
Alfalfa	816 lbs.	4.35
Mixed Hay	803 lbs.	3.75
Stover	821 lbs.	1.94
Silage	7368 lbs.	13.22
Straw	65 lbs.	.17
Bean Pods	97 lbs.	.24
Pasture	23.2 wks.	7.30
Bedding	250 lbs.	.63
Total Feed and Bedding Costs		$54.04
Direct Costs of Hauling Milk		3.80
Miscellaneous Expense		4.48
Special Labor		.02
Net Depreciation on Cattle		5.81
Equipment depreciation		1.65
Total Direct Cost		$69.80
Net Returns Per Cow		$84.65

The following table gives money yields, direct costs, and net returns of poultry on thirty-nine farms in Lenawee, Jackson, and Shiawassee counties for the twelve months ending on March 31, 1922. The total number of hens were 4595 averaging 118 to the farm, and 1922 chickens were raised or 116 to the farm.

ENTERPRISE RECORD ON POULTRY.

DIRECT COSTS.

Items.	Total.		Average per farm.	
	Amount.	Cost.	Amount.	Cost.
Corn	100,145 lbs.	$968 34	2,568 lbs.	$24 83
Oats	41,176 lbs.	409 35	1,056 lbs.	10 50
Wheat	41,506 lbs.	466 27	1,064 lbs.	11 96
Barley	13,792 lbs.	176 01	354 lbs.	4 51
Miscellaneous feeds	31,798 lbs.	464 45	815 lbs.	11 91
Silage	5,896 lbs.	11 29	151 lbs.	29
Skim milk	44,130 lbs.	117 12	1,132 lbs.	3 00
Poultry, net decrease	....	432 93	....	11 10
Equipment, net decrease	....	48 00	....	1 23
Special labor	....	77 30	....	1 98
Miscellaneous	....	80 34	....	2 06
Total direct costs	....	$3,251 40	....	$83 37

MONEY YIELDS.

Items.	Total.		Average per farm.	
	Amount.	Cost.	Amount.	Cost.
Egg sales	17,653 doz.	$4,905 70	453 doz.	$125 80
Eggs for home use	8,305 doz.	2,200 42	213 doz.	56 42
Meat for home use	3,889 lbs.	859 74	100 lbs.	22 04
Poultry, net increaes	....	2,787 48	....	71 47
Manure	153.3 ton	306 60	3.93 ton	7 86
Miscellaneous	....	2 50	....	06
Total money yield	....	$11,062 44	....	$283 65
Enterprise returns	....	$7,811 04	....	$200 28

One of the striking facts of poultry management brought out by the study of these flocks was the effect of protein feeds upon both egg production and net returns per hen.

The average production per hen on eleven farms feeding either tankage or skimmed milk was 96.8 eggs per year. On the other hand, the average egg production per hen on the twenty-five farms not feeding either tankage or milk was only 54.8 eggs per year. The net return per hen in the first case was $2.59 and in the second $1.28, or an added expenditure of twenty cents per bird for the animal protein increased the annual profits $1.30 per hen, or a little more than doubled it.

UNPUBLISHED DATA.

The management of farms in the Detroit whole milk area has been a subject of intensive study since the department was organized, and preceding that time the Dairy Department had carried on route work for two years on 50 farms to determine the cost of producing market milk for Detroit. There are, therefore, three years of unpublished data covering the farming section of the State commonly known as the Detroit Milk Area. This data is now being prepared for publication.

There is also a year's record completed on each of 67 farms on three other types of farming; namely, general farming in Central Michigan, potato farming in the northern part of the State, and feeder farming in the southern portion. These records were completed in April and are now in the process of compilation.

An extended study has also been made of units in farm investment with the purpose of working out basic facts that farmers may use in arriving at conclusions about investments with which they have had little or no experience.

An amount of data for the use of high school teachers of Agriculture in teaching farm accounting has been assembled, mimeographed, and distributed to a group of such teachers. This work has been done in co-operation with Mr. E. E. Gallup, State Supervisor of Agricultural Instruction.

A limited survey of Farmer's Mutual Insurance Companies has been made during the year by Mr. D. T. Musselman.

Respectfully submitted,
HOWARD M. ELIOT,
Professor of Farm Management.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE FARM MECHANICS SECTION.

Director R. S. Shaw,
College.
Dear Sir:

Following is a report of the experimental and investigational work of the Farm Mechanics Section for the year 1921-22.

The work of this Section is reported under three major groups of work. Farm Buildings and Conveniences, Farm and Power Machinery, and Drainage and Land Clearing.

Increased interest in building within the last six months has brought new angles on the building problem. Mr. Fogle has continued the study of barn plans and had hoped to have them ready for publication before this. Study of potato and root storage warehouses was begun two years ago. The last year there has been considerable demand for this material. When potatoes are stored in large quantities the need of some means of control of temperature and humidity of the air has become apparent. Insulation of the building and control of the air movement within seem to be the prime factors. Some time has been given to this problem, principally observing conditions in houses now in use. Considerable study should be given to this problem by making studies of house construction and ventilation systems throughout the winter season. It is hoped that a way may be found to do this work adequately.

A number of projects have been carried through in designing buildings to meet special requirements. While those do not contribute much in the way of scientific data they must be considered as problems and their successful working out as contributing in a cumulative way to good building practice.

In Power Machinery the studies of costs in co-operation with the Farm Management Department gathered from over 300 owners of tractors have been completed.

Some tests of new machines have been made. One of these a rotary distributor lime sower has shown disappointing results when used in a medium to high wind. The other was a rotary gear pump sprayer which bids fair to modify spraying practice if successful. Tests with this pump showed good volume and pressure in delivery, but the spray materials apparently seemed to interfere with the action of the pump. Changes and improvements are being made in its design which may alter its performance.

We have considered tests of a windmill driven electric generating plant now on the market but have not completed arrangements for the installation of the plant.

A tractor mower attachment has been used on the farm successfully this year for the first time, the tractor being used for mowing, raking and tedding. A second tractor was used for drawing the wagon and loader. Two teams were kept on the road hauling and one at the barn operating the hoisting rigging.

A simple lime and marl distributor has also been developed. This machine which can easily be built by the farmer or local mechanic at a cost not to exceed $20 makes it possible for the man who wishes to try a few acres of lime or marl to do so at a permissible cost for spreading equipment.

In drainage little has been accomplished because no one has been in position to concentrate on this problem. The Extension Specialist has given some time to Experiment Station work in installing test wells on the demonstration plots in St. Clair County for determining water levels in the soil. Sample tile have been tested from all the factories except three in Michigan. According to standards adapted by the American Society of Testing Materials, Michigan tile could be improved in several respects.

The Land Clearing specialist has been taking observations on methods of clearing land. One phase of this problem of particular interest to the settler from out of the state is the utilization of material at hand on the land for buildings, fences, gates and various other devices. This material is being gatherd for use as soon as it can be classified and proven of value.

The mechanical and engineering problems on the farm are of endless variety. They are small in their individual applications but gigantic in the aggregate.

Teaching, conferences, and correspondence have robbed men on the College and Experiment Station staff of too much time to give sufficient time to research work. Some means must be found to give investigation the attention it deserves.

It is hoped that in the near future that it may be possible to concentrate on building and drainage problems to a greater degree.

Yours respectfully,
H. H. MUSSELMAN,
Professor of Farm Mechanics.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE SECTION OF FORESTRY.

Dean R. S. Shaw, Director,
Agricultural Experiment Station,
East Lansing, Michigan.

Dear Dean Shaw:

I herewith submit a brief report of the work of the Section of Forestry for the year ending June 30, 1922.

The experimental work on sap flow in the College sugar bush was continued, and records were also kept of all costs and amount of fuel used per gallon of syrup made.

The study of second growth hardwoods on cut-over lands in the northern part of the State was continued. Where fires have not occurred a valuable stand of second growth timber is usually coming up and there is often no necessity for planting in order to obtain a new forest. Methods of handling these lands so as to obtain natural forest reproduction are being studied. A considerable number of sample plots have been taken and separate studies made of the height and diameter growth of trees and the growth in volume of timber per acre. Much of this work has been carried on in connection with the summer forestry camp. It is hoped to complete the study during the coming year.

The experimental basket willow plantation at Spring Lake has been in operation for six years. Record is kept of expenses and profits. It has been showing a profit for the last few years.

A study of returns that may be expected from thinnings in woodlots in the southern part of the State has just been started. This study will include effects of over-pasturing and methods of rejuvenating deteriorated woodlots. Woodlots can play an important part in timber production owing to the fact that they are as a rule located on better soil than other classes of forest and their rate of growth may be greatly stimulated by proper thinnings.

A considerable number of new species have been added to the plot set aside in the forest nursery for foreign trees. We are trying to find trees that will be hardy on the sand dunes of the State and which are immune to certain diseases and insects.

A number of minor projects were also carried on during the year, such as methods of preventing damping off of coniferous seedlings and studies in reducing transplanting losses.

Respectfully sumbitted,
A. K. CHITTENDEN,
Forester.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE HORTICULTURAL SECTION.

Director R. S. Shaw,
Dear Sir:

The following is a brief report of the experimental work of this section for the year ending July 1, 1922.

The investigational work has been concerned largely with such lines of work as have been previously reported. With many of them the work has progressed very satisfactorily but, being long-termed experiments, there is nothing special to report at the present time.

Some very satisfactory results were obtained the past year in the spraying and dusting experiments under Mr. W. C. Dutton. The results of this work have been published in Special Bulletin No. 115, and have also been incorporated in the recommendations of the Section in the new edition of the Spray and Practice Outline, Special Bulletin No. 114, published in co-operation with the Entomological and Botanical Sections.

During the past year a revised edition of the bulletin on Raspberry Culture was published as Circular Bulletin No. 37.

The increasing scarcity of stable manures, the increased cost of labor and the presence in the fruit sections of Michigan of many acres of land too rough and hilly for cultivation make the problem of producing fruit on some system other than the cultivation system, of pressing importance. Hence a summary report of progress of the work in this is of interest to the growers:

CULTURAL PROJECT WITH YOUNG APPLE TREES

Object: To compare the effect of various systems of culture for growing young apple trees in regard to growth and earliness of bearing.

The orchard used in this experiment is known as Blocks X and XI on the Graham Horticultural Experiment Station. The trees are of six varieties planted in groups of four rows each: Duchess, Grimes, Baldwin, Stayman, Spy, Rhode Island Greening.

A cover crop of rye was planted in each of the five plots in this experiment during July of 1919, the year that the orchard was set. In the spring of 1920 it was plowed under about blossoming time and kept dragged every two or three weeks during the growing season.

About the middle of July a cover crop of clover was sown in Plots 1 and 2, and alfalfa in Plots 3, 4 and 5. A very good stand of alfalfa was obtained, but the catch of clover was poor. Plot 2 was re-seeded to clover on a late snow in the spring of 1921, with a good stand as a result. However there was not sufficient growth made to justify removing it when the clover was mowed in June.

In March 1921 a straw mulch was placed around each tree in Plots 2 and 3. The straw was applied in a circle six to eight feet in diameter and about six inches deep. Plot 1 was plowed May 18, 1921, and dragged five times during the growing season. July 29 a cover crop of rye and vetch was sown.

The alfalfa in Plots 3, 4 and 5 were clipped three times during the year. All three clippings were removed from Plot 3. The first clippings from Plot 4 and 5 were placed around the trees as a mulch. The second and third clippings were removed as a hay crop.

An application of one-half pound of nitrate of soda per tree was applied to each tree in Plot 5.

The following is the cost of each individual plot, beginning in March, 1921. Labor costs are calculated at $0.30 per hour for man labor and $.60 per hour for man and team.

Plot 1 (120 Trees): *Clean Culture with Clover Crop*

Labor to 7/29/21	$ 9.00
Cost of rye and vetch	2.00
Total cost of Plot	$ 11.00
Cost per individual tree	.091

Plot 2 (120 trees): *Clover with Straw Mulch*

30-150 lbs. Baled straw at $0.60	$ 18.00
3 qts. clover seed @ $0.20	.60
Straw—one load @ 7.00	7.00
Wire screens placed around trees	3.60
Labor	3.75
Total cost of plot	32.95
Cost per individual tree	.273

Plot 3 (96 trees): *Alfalfa with Straw Mulch*

24-150-lb. bales straw at $.60	$ 14.40
Straw mulch, 1 load @ 5.50	5.50
Wire screen placed around trees	2.88
Labor	10.20
Total cost of plot	$ 32.98
Cost per individual tree	.353
Value of alfalfa removed 2500 lbs. @ $25 T.	$ 31.25
Value of alfalfa removed 500 lbs. @ $25 T.	6.25
Value of alfalfa removed 2000 lbs. @ $25 T.	25.00
Total value of alfalfa removed	$ 62.50
Total cost of plot	32.98
Net profit	$ 19.52

Plot 4 (96 trees): Alfalfa with Alfalfa Mulch, the Second and Third Clippings being Removed from the Plot.

Labor, mowing, raking, cocking, hauling	$ 6.00

Wire screen placed around trees	2.88
Total cost of Plot	$ 8.88
Cost per individual tree	.093
Value of alfalfa removed 500 lbs. at $25 T	$ 6.25
Value of alfalfa removed 1500 lbs. at $25 T	18.75
Total value of alfalfa removed	$ 25.00
Total cost of Plot	8.88
Net profit	$ 16.12

Plot 5 (72 trees): with Alfalfa Mulch—Nitrate of Soda Applied upon the Mulch—the Second and Third Clippings Being Removed from the Plot.

¼ lb. Nitrate Soda applied per tree at 4½c lb.	$ .81
Similar application 18 days later	.81
Wire screens placed around trees	2.16
Labor—mowing, raking, cocking, hauling, etc.	5.10
Total cost of Plot	$ 8.88
Cost per individual tree	.123
Value of alfalfa removed 500 lbs. at $25 T	$ 6.25
Value of alfalfa removed 1000 lbs. at $25 T	12.50
Total value of alfalfa removed	$ 18.75
Total cost of plot	8.88
Net profit	$ 9.87

Excellent results have been obtained in the several fertilizer experiments on tree fruits as carried on in several parts of the State. Detailed results of the experiment in the Farrand orchard have already been published in the Quarterly Bulletin, February 1922, and the results of the many orchards in co-operation with the County Agents have been published in the mid-winter report of the Michigan State Horticultural Society, 1921, and in the papers published by the County Agents.

New projects have been started in breedng, testing and cultural experiments with small fruits on a new ten acre plot leased at South Haven. Also on the work of establishing a source of disease-free raspberry plants in Michigan.

The necessity of pre-cooling cherries and small fruits for distant shipping led to the construction the last spring of pre-cooling plants. This being an essential but new venture for the growers it became necessary for this Section to lend its services in making a success of this practice and in obtaining data on these shipments for future guidance.

Respectfully submitted,
C. P. HALLIGAN,
Horticulturist.

East Lansing, Michigan, June 30, 1922.

REPORT OF POULTRY SECTION.

Director, R. S. Shaw,
East Lansing, Michigan.

Dear Sir:

I herewith submit a brief report of the work of the Section of Poultry Husbandry for the year ending June 30th, 1922.

The inadequacy of the housing facilities for pedigree breeding work greatly hampers our efforts in securing accurate and extensive data on the important problems of "Inheritance of Higher Fecundity and the Mode of Transmission."

A great diversity of opinion is found on this subject among the different poultry authorities.

Our experiments which of necessity are limited and require a further pursuit of the subject, leads us to make the following deductions:

(1) A mendelian interpretation cannot be applied to the Inheritance of Higher Fecundity because this character is neither "dominant" or "recessive". The mating of all high or low production will produce neither all high or all low.

(2) High fecundity is not a sex limited character, but may be transmitted directly to the offspring from either Sire or Dam.

(3) Early maturity is correlated with high fecundity and is usually influenced to a greater degree by the Sire than by the Dam. Extreme precociousness is not, however, a safe criterion of individual laying ability.

Pullet No. 2687 established a new record for early maturity by laying at the age of three months and twelve days. Valuable information will undoubtedly be available, after a further study of this particular pullet and her pen sisters.

(4) High egg production is always associated with constitutional vigor and does not appear to be a unit character. Individual breeding qualities differ, as is shown by the progeny test.

Experiments are being conducted jointly with the Bacteriology Section on Bacillary White Diarrhea. This disease causes enormous losses among young chicks each year and steps are being taken in Michigan to produce and maintain stock free of this infection.

I. To determine whether males may becomes infected and in turn infect females:
  (a) Avenue of infection of males.
  (b) Localization of infection in males.
  (c) Mode of dissemination of Bact. pullorum by males.

II. To determine influence of feeding and environment on the resistance of healthy and infected birds.

III. To determine relation between hens showing diseased ovaries to those reacting to the agglutination test for white diarrhea.

IV. (a) The intradermal test as a means of detecting infected birds.
  (b) Comparison between intradermal and agglutination tests.

V. On the possibility of detecting infected eggs.

This experiment is being continued with very encouraging results.

Respectfully submitted,
E. C. FOREMAN,
Poultryman.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE SOILS SECTION.

Dean R. S. Shaw:

It is again with pleasure that I submit to you the report of some of the accomplishments of the Soils Section of the Experiment Station.

At the close of the fiscal year there were fifty co-operative upland soil improvement projects and twenty muck experimental tracts. In addition the forty acre fertiliy field at Mancelona was laid out. At the latter Station it is proposed to investigate and to demonstrate the best methods for the management of that type of soil. Alfalfa and sweet clover and soy beans are to be used in rotation of different lengths. The value of lime and green manure, different carriers of phosphorus and potassium are to be determined. It is our desire, and in fact our plans call for such, to establish at least one half dozen of these fields on different types of soil and under diverse climatic conditions. We have always steadfastly maintained that owing to the diversity of soil and climate in the State it is essential that this procedure be followed. The people of the State are desirous of this work being done and we trust that we shall be able to accomplish this as speedily as is practicable.

The results from our co-operative projects on the whole are satisfactory. This method enables us to obtain a large amount of information and dispense it with very little cost to the organization. The success may be measured somewhat by requests that we receive for the establishment of additional work. In fact these are so numerous that we can not fulfill more than a small percentage of them.

The salient features that have been brought out by such endeavors may be presented in a few statements. It should be noted that the success of this work is due in a large measure to G. M. Grantham. Where acid phosphate has been used on many plots laid out in the heavy upland soils the increase in the yield of wheat has been such that desirable profits have been obtained. Nitrates have not paid when used on heavier soils except in a few instances. Neither has potash proved to be profitable under existing conditions on such lands yet with the lower prices there may be a place for it under some conditions. On the other hand in the case of sandy soils nitrates have yielded good profits and the use of potash has generally paid where clover and alfalfa were seeded in the grain. On the other hand acid phosphate has been disappointing on such lands in the absence of nitrates or unless accompanied by stable manure. In other words the chief limiting factor in these soils is nitrogen rather than phosphorus and until this condition is corrected phosphorus does not bring results.

In our comparisons of the value of 16% acid phosphate, the 45% or Anaconda phosphate and raw rock phosphate respectively, the former or 16% acid phosphate has proved to be superior up to date. In two cases out of the many the rock phosphate has been profitable. On the basis of the results we have obtained thus far, rock phosphate is not promising on the majority of Michigan farms.

Lime is the keystone in the successful production of alfalfa and sweet clover and is needed on many fields for the satisfactory production of June and Mammoth clover. By the liberal use of lime and the proper amounts of acid phosphate and potash we have been able to establish satisfactory alfalfa seedings in oats and wheat, where the soil has been previously limed. Soil preparation for such practices will govern very largely the acreage of land seeded to alfalfa. From the soil building standpoint it is not sufficient to grow alfalfa on the same land over a long period of years. If it is to be used in this capacity it must be in the rotation and that without the loss of a crop the year it is seeded.

The great increase in acreage of alfalfa in Michigan has been brought about in the main through the use of lime or by correcting the existing soil conditions. We have emphasized this point through our lectures, bulletins and newspaper publicity for more than six years. The attitude of the county agent toward the matter of liming the soil for alfalfa is largely responsible for the present acreage of this crop.

The six years' results from the use of lime on the Cass County fertility field are given below.

SWEET CLOVER.

Fertilizer and hydrated lime, 2,960 lbs	6,640 lbs. green weight
Fertilizer and marl, 4,000 lbs	5,840 lbs. green weight
Fertilizer and (80 mesh) limestone, 4,000 lbs	4,280 lbs. green weight
Fertilizer and (40-60 inch) limestone, 4,000 lbs	3,280 lbs. green weight
Fertilizer and (10-20 inch) limestone, 4,000 lbs	3,440 lbs. green weight

It should be noted that in earlier years of the experiment the finely ground limestone was superior to the somewhat coarser materials. This season, however, the latter are showing up better. The hydrate has been quite effective throughout the period of experimentation. These and other experiments of similar nature are to be continued inasmuch as an important economic question is herein involved.

Another point that our fertility work has brought out is that superior varieties of grain are severely handicapped when placed on infertile soils and in fact remain so a relatively short time under such conditions. Where certified Rosen rye and Red Rock wheat respectively were used in certain places the results obtained with and without fertilizers were as follows:

FERTILIZER ON BEST VARIETIES—CASS COUNTY.

Treatment.	Red Rock wheat.	Rosen rye. rye.
	Bu.	Bu.
Check	3.46	12 0
Limestone	8.25	18.24
L, N, P, K	23.2	28.66

These results are in line with those obtained by Dr. Hopkins by means of a questionnaire sent to workers in different countries.

A. D. Hall, Director of the Rothamsted Experiment Station, Harpenden, England, states that "The direct factor for increase of wheat at the Rothamsted Experiment Station has been the introduction of fertilizers and purchased feeding stuffs. Improved seed does not count for very much. We still grow a good many varieties that were known years ago and they are still among the good if not the best yielders. I should not put down more than 10% of the increase to the new varieties."

von Seelhorst states "In some cases the yield has been increased two and one-half to three fold. In general I assume that of the 100% increase in the yield 50% can be attributed to artificial fertilizers, and to the use of better seed 15%. The remainder can be attributed to better crop rotation and tillage operations."

Schneidewind of the Agricultural Experiment Station, Halle, A. S., Germany, states, "The greatly increased yields which we are now producing in Germany, of our different grain crops, are dependent upon all of the four factors you have named. Of these factors, however, the use of fertilizers takes first rank very decidedly in increasing the crop yields."

The Minister of Agriculture of the Republic of France, Paris, states that the value of approximate figures representing, as near as can be determined, the relative importance of the different factors in increased production is as follows:

Farm Manure and commercial fertilizers	50%
Better preparation of land	30%
Selection of seed and improved varieties	15 to 20%

Gerlach of Bromberg, Germany, states that according to his views each of the four factors set forth has had an essential part in effecting the total increase in yield. He attributes the largest share to the influence of systematically selected higher yielding varieties. The extension and discriminating use of artificial fertilizer has likewise contributed to the increase in yield.

Wagner of Darmstadt, Germany, states, "It is difficult to say which factors have contributed most to increase the yields. If one surveys the last 40 years, it can be well said that the increased yield of the first 20 years was produced especially by the use of fertilizers, but during the last 20 years we recognize also the influence of other factors, which in connection with the ever increasing use of artificial fertilizers have resulted in raising year by year the average crop yields."

The investigations on muck soils have been very satisfactory. The chief features of this work are, as reported by Dr. Paul M. Harmer, given below.

"The work conducted with muck soils may be divided into three phases,—fertilizer projects, cultural experiments and laboratory analyses. Experimental work with fertilizers on all crops has emphasized the need of fertilization for improvement of crop yields, both in quantity and in quality. Cultural experiments have shown the need of heavy rolling of muck soils for improvement of structure and increase of water-holding capacity. Analyses have shown a wide variation in Michigan mucks in chemical composition and in power to absorb and retain fertilizers.

The most significant thing in the results of the fertility work is the fact that different mucks vary considerably in their fertilizer needs. In practically all areas on which plot work was conducted, potash fertilizer was most important in stimulating growth, new or recently burned fields being the only exceptions. Phosphate fertilizer has shown considerable benefit on some but none on others. Nitrate has been beneficial in only a few cases. While farm manure has in the past been considered superior to commercial fertilizers both for general and truck farming, the opposite has been found true in most cases. This is important in that it permits the use of the manure on the upland soils where it is greatly needed.

Fourteen projects varying from one to seven acres in extent are being conducted during the present season, these projects being located in thirteen different counties. Tests to determine both the kinds of fertilizers needed and the rates of application for optimum returns, are being carried on with a number of general farm crops. Results representative of these obtained during 1921 are presented in tables A and B.

TABLE A—EFFECTS OF FERTILIZERS ON SUGAR BEETS ON MUCK

Treatment.	Yield tons per acre.		Percentage sugar.	Sugar pounds per acre.	Percentage purity.
	Tops.	Roots.			
O	5.2	3.5	10.8	504	79.2
N	4.1	3.7	12.3	607	80.6
P	3.6	3.2	12.9	550	85.2
K	6.1	12.3	14.1	2,312	83.8
NP	5.6	4.5	11.2	672	71.8
NK	5.5	16.6	15.8	3,497	87.8
PK	5.2	14.1	15.9	2,989	88.8
NPK	5.1	16.2	16.2	3,499	85.8
M	4.7	15.5	14.8	3,059	87.9

N—nitrate of soda.
P—acid phosphate.
K—muriate of potash.
O—no fertilizer.
M—manure.

TABLE B—EFFECT OF FERTILIZER ON YIELD OF POTATOES.

Fertilizer treatment.	Yield per acre bu. of 60 lbs.
O	49.4
N	66.1
P	59.2
K	147.7
NP	55.9
NK	110.0
PK	126.0
NPK	133.2
M	103.8
MP	107.4
MPL	99.8
ML	121.6

For many years celery growers in Michigan have secured manure from the larger cities for maintaining the fertility of their muck soils. With increase in freight rates and decrease in supply of manure, a greater amount of commercial fertilizer is being used.

Fertilizer experiments with celery on muck have given practically the same results as were secured with general crops in so far as kinds of fertilizers are concerned. The need of nitrate may be more general for this crop.

Table C gives the yields from a representative field, the net returns per acre being calculated. During the present season eight celery projects are being carried on, with special attention given to the rate of application of the various fertilizers. Two similar projects are being conducted with onions.

TABLE C—EFFECTS OF FERTILIZERS ON YIELDS OF CELERY ON MUCK.

Fertilizer treatment.	Yields per acre.		Total returns per acre.	Cost of fertilizer per acre.	Net returns per acre.	Increase or decrease over unfertilized muck with cost of fertilizer deducted.
	Trimmed celery, lbs.	Cases.				
O	10,500	500	$400 00	....	$400 00	....
N	10,000	475	380 00	$10 80	369 20	−30.80
P	11,400	550	440 00	6 00	434 00	34 00
K	12,600	600	480 00	24 50	455 50	55 50
O	10,500	500	400 00	....	400 00	....
NP	11,400	550	440 00	16 80	423 20	23 20
NK	12,800	600	480 00	35 30	444 70	44 70
PK	17,000	800	640 00	30 50	609 50	209 50
NPK	18,000	850	680 00	41 30	638 70	238 70
O	10,500	500	400 00	....	400 00	....
Average check plots	10,500	500	$400 00	....	$400 00	....

Returns from celery calculated at 80 cents per case.

N—Nitrate of soda.
P—Acid phosphate.
K—Muriate of potash.
O—no fertilizer.

Fertilization studies on mint have indicated the need of potash for increase in yield of oil. Of the two sulphate of potash has given somewhat better results than has muriate. Table D shows the yields of green material and of mint oil from one area.

TABLE D—EFFECTS OF FERTILIZERS ON YIELDS OF MINT AND MINT OIL ON MUCK.

Plot No.	Treatment.	Yield per acre.		Lbs. green wt. to produce 1 lb. oil.
		Green wt. tons.	Oil lbs.	
First Crop.				
1	P	14.80	41.75	709
2	K_2SO_4	14.30	52.63	543
3	KCl	14.03	43.75	644
4	Ck	9.51	34.50	551
5	PK_2SO_4	15.06	50.63	595
6	$PKCl$	14.80	40.88	724
Second Crop.				
1	P	5.78	14.62	791
2	K_2SO_4	6.60	15.62	845
3	KCl	5.62	17.52	641
4	Ck	3.60	12.69	568
5	PK_2SO_4	5.56	14.98	742
6	$PKCl$	5.30	15.23	696
Total Crop.				
1	P	20.58	56.37	730
2	K_2SO_4	20.90	68.25	612
3	KCl	19.70	61.27	643
4	Ck	13.11	47.19	556
5	PK_2SO_4	20.62	65.61	629
6	$PKCl$	20.10	56.11	716

The fertilizer problem must be attacked from several angles. It is not sufficient to study simply the effect of certain treatments on the acre yield of crops but the quality of product must be considered. Moreover in order to understand the results obtained when soils are fertilized exhaustive investigations of the reactions between soil and fertilizer salts must be conducted. Our plans call for these researches. Mr. C. H. Spurway is making a study of the latter phases. According to him. "The more important developments of the year's work are listed as follows:

1. A manuscript was recently submitted for approval and publication, outlining: (a) a method for quantitative estimation of the more active soil bases in mineral soils, and (b) a method for quantitative estimation of the base deficiency in acid soils. This study also led to the following conclusions: Soil components, separately or collectively, are amphoteric in nature and the degree of acidity of acid soils is proportional to the ratio between the active bases and acids and not to the excess quantity of active acids; also, the degree of acidity of soils does not correlate with the quantity of base required to neutralize them (lime requirement), but the quantity of base required for neutralization depends upon the total quantity of active acids present in soils in excess of the quantity of active base. These and other points discussed in the manuscript serve to emphasize the validity of conclusions presented in former publications.

2. As an outgrowth of the foregoing described work, a method definitely

based on chemical theory, has been devised for accurately determining the soil reaction. The reaction of soils is considered due to the quantity relationship between hydrogen-ions and hydroxyl-ions in the soil solution, and this relationship is determined by means of an indicator dye (brom thymol blue) and the use of neutral water to obtain a soil extract. This method has several distinct advantages: (a) materials for performing the test may be carried in a coat pocket, (b) It is devised on a sound chemical basis, (c) It is sensitive and accurate, easily and rapidly performed, (d) The reaction of a soil—whether strongly, medium or slightly acid, neutral or alkaline—may be determined with one operation. During the present season, this method has been used successfully by field men of the Soils Section and several county agricultural agents.

3. Some chemical reactions between soils and fertilizer materials have been quite accurately defined and it is hoped that these and other similar data may be made ready for publication soon.

Since the reaction of soils deficient in bases depends upon the active base—acid ratio and since the active components of soils enter into chemical combination with different fertilizer salts, it is concluded that this base—acid ratio in soils has an important scientific and practical significance and it is the plan to work along this line during the coming year."

I desire also to call your attention to the fact that co-operative soil survey work with the United States Department of Agriculture, Bureau of Soils, has progressed satisfactorily, as I reported to you elsewhere. In this work, among other things, we are making a study of the composition of various soil types and their physical characteristics more completely than has ever been done by other institutions. We are preparing a lime requirement map of the various soils of the counties and other popular features, which you will note when you receive the State reports on these various areas.

According to Dr. Bouyoucos, "The research work under the Federal or Adams Fund during the fiscal year ending July 1, 1922, has been conducted on various phases of the three main projects which have been under investigation at this laboratory for the past several years, namely, soil temperature, soil solution and soil moisture.

Some of the specific problems which have been investigated during the year are as follows:

(1) Causes for the difference in frost occurrence between peats and mucks and mineral soils.
(2) Relationship between heat of wetting, moisture equivalent and unfree water.
(3) Movement of soil moisture from small capillaries to large capillaries upon freezing.
(4) Effect of chemical agents on oxidation in soil forming rocks and minerals.
(5) The freezing point and dilatometer methods.
(6) Further studies on the solubility of rocks, mineral and soils and the chemical nature of their solution.
(7) Heat of wetting of soils, rock and mineral powders in various organic and inorganic liquids and in water.
(8) Further studies on frost occurrence and the possible method of preventing damage to crops.

(9) Studies on soil structure.
(10) Establishing methods of studying and determining the colloids in soils.
(11) Study on the activity of soils.

Preliminary or final reports have already been prepared for the first five problems and are being published as scientific articles in Soils Science and in the Journal of Agricultural Research. The investigation of the other six problems is being continued."

On the basis of these results and general conditions in the State I maintain that the financial support of soil investigations is woefully deficient. The expenditures for this Section, aside from salaries, since it was reorganized in 1914, as furnished by J. Schepers, Treasurer, are as follows:

Disbursements of Experiment Station Soils for the following years:

Year ending	
June 30, 1914	$ 561.04
June 30, 1915	1,159.21
June 30, 1916	1,371.08
June 30, 1917	3,334.58
June 30, 1918	2,737.78
June 30, 1919	4,084.44
June 30, 1920	4,761.40
June 30, 1921	14,874.61
June 30, 1922	12,356.31

Respectfully submitted,
M. M. McCOOL.
Prof. of Soils.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE UPPER PENINSULA EXPERIMENT STATION.

Director R. S. Shaw:
Dear Sir:

I herewith submit a brief report of work done at the Upper Peninsula Experiment Station for the fiscal year ending June 30, 1922.

The crops experimental work was in charge of Mr. G. W. Putnam for the first half of the year and of H. R. Pettigrove during the latter part. The plant disease work has continued in charge of Mr. J. E. Kotila. Both of these departments have increased their work considerably over previous years.

LAND CLEARING.

Seventy-one acres have been cleared during the past year and fifty acres of this have been plowed and the larger part of it is in crops this year.

The cost of clearing this land has varied from twenty to fifty dollars an acre depending largely on whether the land had previously grown hardwood, or cedar and tamarack.

FENCING.

Three and one-half miles of woven wire fence was erected. This completely incloses the Station land and the fields that are now under cultivation. The road fence in front of the Station buildings was torn down and new fence built. The old barnyard fences were torn out and replaced by new ones.

PAINTING.

The crops experimenter's house and the superintendent's house have been painted in the past year and some interior decorating done to these houses, and also the boarding house and office.

BUILDINGS.

The manure pit has been completed and an inclosed porch built on the superintendent's house.

MACHINERY.

Some new machinery has been added to the equipment. Among these is a side delivery rake, high pressure spray rig, pea thresher, corn binder and several smaller pieces.

CROPS.

The crops of 1921 were very light owing to the dry weather and the grasshoppers. Prospects this year however, are much brighter as the hay crop is heavy and all other crops are showing up especially well with the exception of corn and the more delicate garden crops.

A large percentage of the land in small grains was used for increase fields of pedigreed seed grain. Fourteen acres were put into sunflowers this year so that we would have plenty for silage and for experimental work with dry fodder. About twelve tons of dry sunflower fodder was fed last year to sheep with fairly good results and this year it is planned to carry on experimental work in feeding the same.

SHEEP.

We now have 523 sheep and lambs in the flock of pure bred Rambouillet, Hampshire and Shropshire breeds and grades and cross breeds of the same. Each individual is numbered and records are kept of the weight of lamb at birth also at shipping time, weight of fleece and number of lambs produced by the different breeds and crosses. Many of the pure bred ram lambs are sold to the farmers as breeders and the grade ram lambs, cull ewes and inferior pure bred lambs are shipped to Chicago for slaughter.

DAIRY.

We now have fourteen pure bred Holstein cows, one herd bull, three bull calves, six heifer calves and six yearling heifers. Five bull calves and one heifer calf have been sold to farmers in the past year. The herd bull Emblagaard Colantha Bonastine was sold for beef last fall and he was replaced by Canary Segis Beets, bred by the Newberry Hospital. One heifer calf was given as a prize to the boy or girl having the highest individual score for judging dairy cattle at our last annual Farmers' Round-Up.

HORSES.

No change has been made in horses during the past year. We now have two work teams and one general purpose horse.

POULTRY.

A flock of fifteen white Leghorn birds has been added to the Station flock. We now have a small flock of White Leghorns and Barred Rocks. No particular experimental work has been done with them. The eggs during the hatching season were largely sold to farmers and the balance of the time were sold to the boarding house or private individuals.

The following are the reports of the Crops experimental and plant disease work done at this Station.

Mr. D. L. McMillan,
Supt. U. P. Experimental Station.

I herein report the experimental crop work at this Station for the year ending July 1, 1922.

The experimental work carried on in oats consisted of a variety test of commercial and pedigreed oats. In the commercial oat test, Wisconsin Pedigreed No. 77, Iowa No. 103, Silvermine and 60-day oats out yielded the other varieties. Wisconsin pedigreed No. 14 being the low yielder. The Pedigreed variety test showed that the 60-day oats, Wisconsin Pedigreed No. 77 and Iowa No. 103 were the highest yielders. Wisconsin Pedigreed No. 5 being the low yielding oat.

The Pedigreed Barley test showed that the Wisconsin Pedigree No. 9 and Michigan Black Barbless gave the highest yields. A few varieties of Spring Rye and Spring Wheat were also tested in this series.

In a variety and date of planting test it was found that Black Barbless Barley gave the highest yields with Michigan-two-row Barley following. The date indicated that about the middle of May was the best time to seed.

The time of planting winter wheat indicated that the latter part of August was the best time to seed, (August 30 indicating the best yield.) A winter wheat date of planting and variety test was seeded in the fall of 1921.

A series was devoted to testing of annual hay crops. Oats and peas gave the best returns with oats and vetch as the next highest yielder.

A commercial pea variety test was made to find a high yielding pea in forage as well as seed. The English Field Pea gives promise of being a good sort.

A sunflower series devoted to rate and spacing showed that everything favored the thirty-inch row at the rate of 6 lbs. per acre. This also gave the best quality ensilage.

The potato work included the cultural plots, seed treatment, date of planting, hill units, and tuber unit increase. Mr. J. W. Weston and Mr. J. E. Kotila co-operating in this work.

Another series was devoted to sugar beets and the possibilities of seed production. The sugar beets did not come through the winter very well. only 15 to 30% surviving.

Co-operative work was carried on with Professor J. A. Jeffrey on sandy and mucky soils at Wetmore and Seney respectively. There were also co-operative plots in the various counties. In most cases the grasshoppers and dry weather destroyed all possibilities of obtaining results. The few cases which did come through showed results as indicated previously as to varieties.

The following work will largely constitute the work for this year, 1922.

Series of the commercial oat varieties has been continued and also the pedigreed oats with a few varieties added to the latter from some of the northern stations.

The commercial field pea plots are still being carried with a few varieties added to this.

The barley variety series is continued with a rate of seeding of both oats and barley ranging from one and one-half bushels to four bushels per acre. A small series of spring wheat plots are also being grown.

The potato work will be continued as last year. A few varieties are planted in a large increase field for the beginning of better strains for distribution. Mr. Weston and Mr. Kotila co-operating in this work.

The annual hay crop and sunflowers will be continued as of last year. A little work with corn and soy beans is being done. A few earlier types of corn are being grown in ear to row work.

A new project on the testing of Red Clover was begun. There being twenty-seven strains, obtained from some of the states and a few from Foreign countries.

Sugar beets will be continued to see what can be done in the production of seed. This will be largely cultural work to maintain the plants over winter.

There is also at present about twenty acres of increase into barley, eight acres of peas and two acres of oats, for distribution.

Co-operative tests are being conducted in the various counties with oats, barley, alfalfa and sweet clover; also the work is being continued with Professor J. A. Jeffrey at Wetmore on the Sandy area and at Seney on the Muck swamp area.

Yours very truly,
H. R. PETTIGROVE,
Crops Experimenter.

Mr. D. L. McMillan,

Supt. of the U. P. Experiment Station.

Dear Mr. McMillan:

Report of the potato disease investigations carried on at this Station in co-operation with the Botanical Section of the College for the year ending June 30, 1922, is hereto appended.

Weather conditions during the 1921 season were not favorable to the potato disease in general. Owing to the dry hot weather which prevailed during the early part of the summer, Blackleg was of very minor importance and no cases of Late Blight, which is also associated with cold wet seasons, were reported. It was very difficult to diagnose such diseases as Mosaic and Leaf Roll, especially on the early planted tubers. The weather conditions of the season however, were very favorable to the potato leafhopper. The adult leafhoppers emerged early and due to the comparatively high temperature the eggs hatched and the nymphs grew to maturity in a minimum length of time. The result was that hopperburn was severe and caused considerable reduction in yield.

Observations on the life history of the Potato Leafhopper, Empoasca mali LeB, which causes hopperburn were continued and control measures were demonstrated. Bordeaux mixture was found to be effective in warding off the leafhoppers and thus indirectly controlling hopperburn.

An acre of potatoes was devoted to spray and dust experiments. The effectiveness of Bordeaux mixture as a spray for potatoes was demonstrated.

Potato seed treatment experiments were carried on after the plan of the preceding year. In addition, soil treatment experiments were conducted in an attempt to control potato scab, which seems to be inherent in some of the limestone soils of the Upper Peninsula. Approximately an acre of land was devoted to these trials.

The laboratory which was built during the early summer on the second floor of the office building afforded an excellent place to carry on studies on the casual organisms of the various diseases affecting the potato. The laboratory work was somewhat impeded through lack of pressure water and drain for waste water, and in the latter part of the season through lack of good artificial light. The need of electric lights was sorely felt. As a whole, however, the laboratory is a marked improvement over conditions of the preceding year.

I take this opportunity to thank you for the hearty co-operation and assistance you have given to further the potato disease investigations at the Station.

J. E. KOTILA,
Research Ass't in Plant Pathology.

Respectfully submitted,
D. L. McMILLAN,
Superintendent.

East Lansing, Michigan, June 30, 1922.

REPORT OF THE DIVISION OF EXTENSION WORK.

President David Friday,
Dear Sir:

The work of the Extension Divison is fully reported upon by the leaders of the various projects which have been approved by the Secretary of Agriculture under the terms of the Smith-Lever Act. For each year, a detailed annual plan of work for each project is required to be submitted to the Federal Office for approval. The projects for the year are listed below, and the report for each line of work is appended hereto.

1. Administration.
2. County Agricultural Agents.
3. Home Economics.
4. Home Demonstration Agents.
5. Boys' & Girls' Clubs.
6. Farm Crops.
7. Live Stock.
8. Horticulture.
9. Potatoes & Vegetables.
10. Soils.
11. Farm Management Demonstrations.
12. Insect Control.
13. Household Engineering & Drainage.
14. Markets.
15. Poultry.

The relationship of the Extension Service to the farm organizations has continued to be one of close harmony. The strong development of County Farm Bureaus has resulted in more available funds locally, which have been used to retain the services of agents who would otherwise have left the work. This decrease in "turnover" of county agents has greatly strengthened the staff. It is also true that the growth of these organizations has increased the importance of the position of county agent, necessitating a high standard in selecting new men.

The increase in Farm Bureau membership has greatly stimulated and in some ways modified the extension work. The first interest of the newly created County Farm Bureaus was toward marketing. This was, no doubt, due to the conditions of the time and to the ambitious promises of membership solicitors. This condition has been met by assisting the producers in the organization of marketing institutions in centers where financial conditions, volume of business and local leadership gave promise of success. The extent of this movement is shown in the appended report on "Marketing". The later tendency is to return to greater interest in the various lines of production, especially in economy of production and higher grades of produce. This is offering the Extension Service unusual opportunities for work in standardization of varieties of grains, potatoes, fruits and breeds of live stock, because through marketing organizations, the producer benefits directly from the superior article which he has to sell.

The State Horticultural Society, which includes the prominent fruit growers, has been brought into close touch with the College through the appointment of the Horitcultural Extension Specialist as its Secretary. Through its special committee on "Extension Work", Mr. Farrand is able to place his plans favorably before the horticultural leaders and obtain their criticisms, suggestions and support. This arrangement has already elevated horticultural extension work from an unsatisfactory condition to one of real service to a great industry. This service must soon be expanded.

The "Radiophone", which had its beginning during the fiscal year, may yet vitally affect the methods used in extending information to the people. Through co-operation with The Detroit News, twelve different speakers have given extension radiophone lectures on Saturday evenings from the WWJ Broadcasting Station in Detroit. The results cannot be estimated, but reports from widely scattered places have come in on nearly all of these lectures. It now seems that a broadcasting station at the College will soon be a necessity. This method may not replace any part of our present extension system, but it will certainly add one more way of reaching the people.

The most important development in extension methods has been in the character of winter meetings. It has been felt by many of the staff that a large percentage of farmers did not attend the usual meetings in town or local meeting place. To meet this condition, an intensive campaign by counties was planned with day meetings to be held on farms in each community with larger meetings in towns at night. The daytime barn meetings proved to be a success in reaching many who had previously been entirely out of contact with this work. This campaign method was used in ten counties in promoting alfalfa growing and dairy herd improvement. The results are reported in another place, but it is to be noted here that this method will be further perfected.

Yours very truly,
R. J. BALDWIN,
Extension Director.

East Lansing, Michigan, June 30, 1922.

PUBLICATIONS.

Edition.	Bulletin No.	Title.	No. Pages.	Author.
20,000		Better Bulls for Michigan	4	J. A. Waldron
8,000	22	Effective Crops Exhibits	24	H. C. Rather
8,000	11 (revised)	Handicraft Work		
5,000	28	Home Canning Guide	2	Home Econ. Dept.

Appointments:

L. F. Livingston, Land Clearing Spec., July 1, 1921.
H. B. Killough, Farm Mgt. Dem., July 1, 1921.
A. C. Baltzer, Dairy Husbandry, Spec., July 1, 1921.
Eva Schurr, Home Dem. Agent, Ottawa, July 1, 1921.
Dorothy Kurtz, Home Dem. Agent, Saginaw, July 1, 1921.

Viva Osborn, Club Agent, Branch, July 1, 1921.
L. W. Ross, Club Agent, Wayne, July 15, 1921.
Jennie Williams, Home Dem. Agent, Gogebic, Aug. 1, 1921.
Muriel Hopkins, Nutrition Spec., Sept. 1, 1921.
P. M. Harmer, Muck Soils Spec., Sept. 1, 1921.
Muriel Dundas, Home Dem. Agt., Gladwin, Sept. 15, 1921.
Sylvia Wixson, Home Dem. Agt., Marquette, Sept. 15, 1921.
R. G. Carr, Ass't State Ldr. Co. Agts., Nov. 16, 1921.
C. V. Ballard, Ass't State Ldr. Co. Agts., Dec. 1, 1921.
C. E. Ferguson, Poultry Husbandry Spec., Jan. 1, 1922.
H. E. Dennison, Dairy Husbandry Spec., Jan. 1 1922.
G. W. Putnam, Farm Crops Spec., Jan. 1, 1922.
Ruth Cresswell, Ass't State Ldr. B. & G. Clubs, Feb. 1, 1922.
Nevels Pearson, Ass't State Ldr. B. & G. Clubs., March 1, 1922.
W. C. Boman, Club Agent, Calhoun, March 1, 1922.
L. E. Mericle, Club Agent, Genesee, April 1, 1922.
A. L. Watt, Club Agent, Washtenaw, April 1, 1922.
L. D. Kurtz, Farm Crops Spec., April 1, 1922.
H. M. Harman, Entomology Spec., May 10, 1922.
Helen Simonson, Dist. Home Dem. Agt., March 1, 1922.
R. M. Roland, County Agent, Calhoun, July 8, 1921.
B. O. Hagerman, County Agent, Charlevoix, April 1, 1922.
T. R. Shane, County Agent, Chippewa, Aug. 1, 1921.
R. D. Bailey, County Agent, Crawford, July 1, 1921.
J. E. Turner, County Agent, Delta, April 15, 1922.
R. W. Tenny, County Agent, Eaton, Dec. 1, 1921.
D. C. Cavanaugh, County Agent, Emmet, Dec. 8, 1921.
Clayton Cook, County Agent, Gratiot, July 1, 1921.
C. P. Pressley, County Agent, Gratiot, March 1, 1922.
E. E. Twing, County Agent, Huron, Oct. 3, 1921.
H. L. Carr, County Agent, Ionia, May 1, 1922.
Earl Roberts, County Agent, Iron, March 1, 1922.
R. E. Decker, County Agent, Jackson, Dec. 1, 1921.
L. L. Drake, County Agent, Antrim and Kalkaska, Oct. 1, 1921.
K. K. Vining, County Agent, Kent, Dec. 1, 1921.
A. J. Patch, County Agent, Lapeer, August 24, 1921.
C. L. Coffeen, County Agent, Lenawee, May 1, 1922.
C. L. Bolander, County Agent, Livingston, May 10, 1922.
W. N. Clark, County Agent, Ontonagon, Feb. 15, 1922.
C. W. Wing, County Agent, Osceola and Lake, March 6, 1922.
T. R. Shane, County Agent, Schoolcraft, Feb. 1, 1922.

Temporary County Club Agents:

Alba Stenson, Baraga.
Geo. E. Butterfield, Bay.
Wanda Brunni, Gladwin.
K. P. Silberg, Gogebic.
H. B. Dimmers, Hillsdale.
Glenn J. Waite, Jackson.
Grace M. Watson, Kent.
M. R. Cameron, Luce.
F. H. Dexter, Monroe.

Geo. H. Kimball, Oakland.
Evelyn Kinney, Osceola.
Carrie Moore, Schoolcraft.
O. C. Goss, VanBuren.

Resignations:

J. A. Waldron, Dairy Husbandry Spec., June 30, 1922.
Aurelia Potts, Ass't State Ldr. H. Dem. Agts., Feb. 28, 1922.
R. N. Hain, Insect Control Spec., March 31, 1922.
Donald Williams, Sheep Husbandry Spec., Feb. 28, 1922.
A. L. Bibbins, Farm Crops, Dec. 31, 1921.
E. C. Foreman, Poultry Spec., Nov. 30, 1921.
Helen Pratt, Home Dem. Agt., Chippewa, Jan. 31, 1922.
Dorothy Kurtz, Home Dem. Agt., Saginaw, Nov. 30, 1921.
Sylva Richardson, Home Dem. Agt., Gogebic, July 31, 1921.
Helen Simonson, Home Dem. Agt., Dickinson, Dec. 31, 1921.
Bernice Woodworth, Home Dem. Agt., Allegan, June 30, 1921.
W. C. Boman, B. & G. Club Agt., Wayne, July 15, 1921.
D. C. Cavanaugh, B. & G. Club Agt., Sanilac, Nov. 30, 1921.
R. W. Tenny, B. & G. Club Agt., Eaton, Nov. 30, 1921.
B. O. Hagerman, B. & G. Club Agt., Washtenaw, Dec. 31, 1921.
A. L. Strang, B. & G. Club Agt., Saginaw, March 31, 1922.
L. V. Benjamin, County Agent, Baraga, May 31, 1922.
P. C. Jamison, County Agent, Calhoun, July 15, 1921.
C. W. Wing, County Agent, Charlevoix, Dec. 31, 1921.
T. R. Shane, County Agent, Chippewa, Jan. 31, 1922.
R. E. Decker, County Agent, Eaton, Nov. 30, 1921.
K. K. Vining, County Agent, Emmet, Nov. 30, 1921.
Clayton Cook, County Agent, Gratiot, Nov. 30, 1921.
James Campbell, County Agent, Huron, Oct. 6. 1921.
W. F. Manby, County Agent, Iron, Jan. 31, 1922.
C. V. Ballard, County Agent, Jackson, Nov. 15, 1921.
E. E. Twing, County Agent, Kalkaska, Oct. 1, 1921.
R. G. Carr, County Agent, Kent, Dec. 1, 1921.
S. T. Wellman, County Agent, Lapeer, Aug. 24, 1921.
Ralph Carr, County Agent, Lenawee, March 31, 1922.
F. S. Dunks, County Agent, Livingston, Feb. 28, 1922.
C. P. Pressley, County Agent, Schoolcraft, Dec. 31, 1921.

REPORT OF EXTENSION WORK IN AGRICULTURAL ENGINEERING.

BY H. H. MUSSELMAN, GENERAL EXTENSION; O. E. ROBEY, DRAINAGE AND HOUSEHOLD ENG. SPEC.; L. F. LIVINGSTON, A. J. MCADAMS, GEO. AMUNDSON, LAND CLEARING SPECIALISTS.

GENERAL FARM ENGINEERING.

A great deal of the extension work in Farm Mechanics calls for the solution of a great many individual problems not always of like character in a community at one time. For this reason, the campaign method of extension is not always effective. Household Mechanics is one of these subjects. This has been handled this year largely by means of model spetic tanks, blueprints and other matter furnished through the County Agent. The work has suffered somewhat in the past four years because we have not felt justified in urging the farmer to make expenditure with the disparity in prices between agricultural and manufactured products. However, with a readjustment of conditions and a revival of interest in buildings and improvement more effort should be concentrated on water supply and sewage disposal problems.

The county campaign plan of Extension in Drainage has been effective where it has been tried, and should be carried into other counties where there is a general need of drainage. It is also felt that this work should be intensified to make it effective.

We have been called upon to assist in working out a number of projects this year which may be considered extension work. The State Administrative Board has sought our assistance on state farm building layout and planning. Several fruit and potato storage houses have been planned. For this assistance there will be more demand. Barn and other building projects have been carried through and many blue-prints have been sent out as sketches, plans and details.

We need especially in this work a plan of following up and reporting on the work which has been done.

HOUSEHOLD ENGINEERING.

The work in household engineering has consisted of holding demonstrations in septic tank construction and furnishing plans for various household conveniences. Also attendance at meetings where household conveniences were discussed.

DRAINAGE.

Drainage extension work has consisted of making drainage surveys and providing plans for drainage systems. A drainage campaign was put on in Sanilac county according to the plan submitted last year and has proved quite successful. A series of meetings were held during February and March to bring before the people the value of drainage. As a result

22 farmers asked to have drainage plots of various sizes ranging from 7 to 25 acres put in on their farms. Also, 68 farmers asked to have their farms surveyed for future drainage systems. Two demonstration meetings have been held in the fields, which were attended by about 100 people. Publicity articles were run in the county papers regarding the work.

Thirteen days were spent in testing the tile of the various manufacturers of the State. Many interesting points were brought out of this test which will serve as a basis for future study.

SUMMARY.

Number of days spent in office	52
Number of days spent in tile testing	13
Number of demonstration meetings held	13
Attendance	381
Number of Lecture meetings held	38
Attendance	2512
Number farms visited	103

LAND CLEARING.

Agitation for land clearing has been carried on for some time in Michigan, but it was not until August 1, 1921, that the efforts were crystallized and the Michigan Agricultural College established a land clearing section with L. F. Livingston in charge and A. J. McAdams as assistant. Due to the early growth of the work, Geo. Amundson was employed in March as an assistant. The first problem that confronted this office was a general survey of the land clearing conditions of the State with special reference to the Upper Peninsula where more cleared land was essential. The survey brought out several facts regarding the agricultural situation of the Upper Peninsula. 1. Land clearing with its problems is the most important question facing the farmers in the cut-over sections. 2. The average of cleared acres per farm is too small to make economical and successful farming. 3. The rate of clearing, based on a ten year average was one acre per farm per year, much too slow for the development of resources at hand. 4. The reasons for this slow rate of clearing by the settlers already on the cut over regions, were found to be several; lack of knowledge of the economical methods of clearing, wasting explosives through improper handling and buying, too many accidents due to improper use of explosives, and a lack of interest and understanding of the problems of land clearing on the part of the bankers and business men.

Land clearing in the cut over regions of Michigan, while ordinarily classed as reclamation work, differs from most reclamation projects. Here the soil, rainfall and climate are naturally provided and adapted to agriculture. The sole obstacle is the brush and stumps which must be removed before the land can be tilled. Every farmer in this territory is confronted with the same problem, and every farmer, without exception, can be benefited financially and socially by an intensive campaign in better, quicker and safer methods of clearing.

In this respect, land clearing differs from other reclamation work in the State. It is a problem which must be worked out by every settler and some program is absolutely essential to take care of the farmers now developing new homes, and new men who will eventually develop the rest of this territory, to give them the benefit of all past experience and some definite aid, if this territory is to become a prosperous farming section.

To accomplish this it was necessary to interest all whom have mutual enterprises in the Upper Peninsula to the importance of more cleared acres, and to secure their continued co-operation.

The work was carried on through: 1. demonstrations in uses of dynamite and picric acid, 2. land clearing exhibits at county fairs, 3. meetings with county boards of supervisors, 4. winter farmers meetings, 5. business organization meetings, 6. newspaper publicity, 7. land clearing schools, 8. land clearing story contests and 9. picric acid distribution.

Thirteen demonstrations in the use of dynamite and picric acid were held in the Upper Peninsula with an attendance of 2170 farmers. This clearly indicated the need of education on the use of explosives as well as need of education in the use of stump pulling equipment. From our survey, it is estimated that one-third of all the dynamite used for agricultural purposes is wasted because of improper methods or the wrong materials being used. Further, it was found that one-half of all stump pullers purchased should never have been bought. Either the type of clearing was not adapted to stump pullers or the machine was not equipped with the right attachments. The carload system of buying explosives was introduced and saved the farmers thousands of dollars. By correcting these faults, the cost of clearing has been and can be reduced to a much lower figure.

It was necessary to get the land clearing movement before the eyes of everyone in the Upper Peninsula and to spread broadcast information that the Michigan Agricultural College was in a position to help farmers in their land clearing work. To do this, we chose to visit all county fairs with a land clearing demonstration by means of models, showing the best approved methods and tools as well as featuring models of home made devices. During the fall, twelve counties were visited and a total of 19,575 people viewed the land clearing exhibit. In personal talks with various farmers, the need of education was again evident.

To further the educational end of land clearing and to secure the necessary funds to carry on our plans, we appeared before nine county boards of supervisors asking them to appropriate sufficient funds to carry on a series of land clearing schools in their counties. We received an aggregate appropriation of about $8,000 to carry on thirty-eight land clearing schools in ten counties of the Upper Peninsula. In the majority of cases, the board of supervisors were far sighted enough to see the necessity of land clearing and in several cases they attended the schools in a body.

During the winter a total of 105 land clearing meetings were held in the farming regions with an attendance of 10,045 people. A conservative estimate shows 65% were farmers. Twelve counties were covered during the winter. Moving pictures portrayed the best approved methods of clearing land and arrangements were made for the land clearing schools to be held in the spring. These meetings demonstrated a good healthy interest in land clearing, and our office has been called on continually to aid farmers in their problems. These meetings also revealed that it was necessary to show better uses of material on hand and to bring about a cheaper rate of clearing, as well as to get cheaper materials in the hands of the farmer. In many cases, it was found the cash outlay played an important part in the manner in which the farm was cleared. In other cases, the *speed* of clearing was the determining factor with no particular attention paid to the cash outlay. Therefore, that which is economic land clearing for one may be impossible for another, and this is one of the many reasons for bringing land clearing education as near the individual's back door as possible.

Besides interesting farmers, it was necessary to show business men and bankers the direct relations between more cleared acres and more rapid development of their community or city. It was our privilege to appear before 25 business men's meetings with an attendance of 1792. By gaining their co-operation and support, the land clearing movement took enormous strides forward. During the winter two county agents' conferences were held where land clearing was the main subject of discussion and in the majority of cases, land clearing was one of the major projects in the year's work of the county agents. From the county agents' reports, we find they spent 25.8% of their time on land clearing.

Since last fall, this office has supplied twenty-five newspapers of the Upper Peninsula each week with land clearing material. Our clipping book shows that these papers as well as several in the Lower Peninsula and numerous farm magazines have been supplied with information. Because of our wide publicity campaign, we have received requests for information on land clearing and possibilities of land clearing, stretching from New York to Seattle and as far south as Central America.

To interest the young folks and also to further interest the older folks in land clearing, a land clearing story contest was carried on in each of six counties. Over a thousand essays were submitted and prizes were awarded to the winners.

Practical land clearing education was carried on this spring by a series of 38 land clearing schools conducted in ten counties of the Upper Peninsula. Over 10,000 people attended these schools. The school was made up of eight cars donated by the railroad; 18 men, supplied by the College; six stump pullers, supplied by stump puller companies; two tractors, supplied by the tractor companies; and dynamite and dynamite tools from three powder companies as well as picric acid. The "learn by doing" method was adopted in the field, clearing a total of 86 acres. About 2706 farmers took the complete course. We know that everyone who attended these schools carried away some ideas which will be beneficial to him.

It was also the duty of this office to distribute 636,000 pounds of war salvage picric acid to the farmers of the State. This was done through the county agent system, farm bureau organizations, and county clerks. Fourteen cars of 300,000 pounds were placed in 15 counties of the Lower Peninsula and the remaining 13 cars, or 336,000 pounds were distributed in 14 counties in the Upper Peninsula. It is estimated that 12,000 acres of land were cleared with this explosive at a saving to the farmers of about $65,000.

	No.	Attendance	Counties Visited	Days
Demonstrations held	13	2170	8	15
County Agent Conferences	3	60		5
Exhibits at county fairs	12	19575	12	44
Business men's meetings	25	1792	14	30
County Board meetings	9	247	9	9
Farmers' meetings	105	10045	12	75
Land Clearing Schools	38	10000	10	70

REPORT OF EXTENSION WORK IN APICULTURE.

BY EDWIN EWELL

The educational program of the Extension Specialist has consisted of many personal interviews with beekeepers; participation in a series of "beekeepers' schools" in thirty counties, each school lasting two days; local meetings held in various counties at which demonstrations were given whenever possible; and automobile tours, which offer one of the most desirable methods of demonstration. The tour is advertised in advance by the officers of the county associations, and beekeepers assemble at the starting point with their automobiles, visiting a series of apiaries during the day. Each apiary as visited is examined by the entire party and demonstrations made of the treatment of diseases, requeening, making of increase and various types of equipment. In this manner, through comparison of various apiaries, the beekeepers in attendance recognize superior methods of manipulation and the advantages of using up-to-date equipment. At the same time discussion of problems and manipulation help to discover the individual needs of beekeepers in the party. Proper methods of manipulating supers, care of the honey crop and its preparation for market were given much attention; the proper manipulation of new swarms and reasons for swarm control were also stressed.

Exhibits were displayed at four fairs: Detroit, Saginaw, Bay City and Midland. Opportunity was presented to meet a large number of beekeepers in each case. The College exhibit consisted of samples of honey from various sources, mounts of honey plants, wall charts and samples of foulbrood, all of which excited much interest. In fact it was necessary to give an almost continual lecture during each day of each fair. Opportunity was presented to make plans for extension work among new prospects. It has been our policy to instruct beekeepers regarding bee diseases and to encourage each beekeeper to become an expert in its detection and treatment. Inasmuch as disease is spread throughout the Lower Peninsula with the exception of the northern tier of counties, we hope that in each community at least one or two men, having become expert in handling disease, may serve as leaders in influencing others to adopt better methods.

Work done in five counties in the Upper Peninsula indicated a wonderful opportunity for the development for the bee keeping industry there. Although there are few commercial beekeepers in the Upper Peninsula at the present time there are many beginners. Large areas of clover, raspberry, fire-weed, golden-rod and other honey-plants produce annually a large quantity of nectar which goes to waste for lack of bees to gather it. Although the winters are long and cold, large quantities of snow and a steady temperature enable the beekeeper to winter his bees successfully, if proper care is given.

Since the Upper Peninsula is at present free from disease, "Cloverland" is becoming very attractive to beekeepers.

The increase in acreage of sweet clover throughout the State is assisting beekeepers generally since raspberry and other nectar sources from wild plants are becoming fewer.

Through the co-operation of large numbers of County Beekeepers' Associations, and of the County Agricultural Agents, it is becoming possible to reach more and more beekeepers each year. Several county beekeepers' associations have definite schedules for meetings for the year, the plan providing for from two to five meetings, most of which are held during the summer months. The interest exhibited by these County Associations depends largely upon the officers in charge. However, there is a growing feeling that co-operation is beneficial to all and that the County Beekeepers' Associations offer the best means to this end, both educationally and commercially.

REPORT OF EXTENSION WORK OF BOYS' AND GIRLS' CLUBS.

BY R. A. TURNER

Boys' and Girls' Extension Work in Agriculture and Home Economics has been carried on as one of the projects of the Extension Division at the Michigan Agricultural College.

That club work has made a very definite contribution to good farm practice and to farm home life is proved in the results attained during the past several years. Not only have these results strengthened the extension program as a whole, but they have also created an interest in improved rural work and rural life.

Boys' and Girls' Club Work is organized agriculture and rural leadership in the making. To train this rural leadership is one of the goals of the Club Department.

Clubs have been organized in the following projects:

Summer Season

Corn
Potato
Bean
Garden
Poultry
Pig (Breeding)
Sow and Litter
Dairy Calf
Dairy Heifer
Cow and Calf
Baby Beef
Sheep
Canning
Meal Preparation

Winter Season

Clothing
Own Your Own Room
Handicraft
Hot Lunch

COUNTY ORGANIZATION.

The relation of the county farm bureau to the projects carried on in any given county is one of co-operation in determining these projects. In many counties a program of work is determined by the representatives of the bureau and the extension agents. The club agent's program of work is such as to harmonize with this county program.

The work of the county club agent is financed co-operatively by the U. S. Department of Agriculture, the Michigan Agricultural College and, in a majority of cases, by the county farm bureau. The local club leaders do not receive any salary for their work. Often, however, a member of the farm bureau executive committee is a local club leader. In certain counties, one or more members of the executive committee will be designated as being responsible to the executive committee for the club work of the county.

CLUB CAMPS, FAIRS, TRAINING SCHOOLS.

The Second Annual Club Camp for club members of the Upper Peninsula was held at the College Experiment Station at Chatham on August 8, 9, 10 and 11. One hundred club members and 10 leaders attended the camp. Features were the poultry demonstrations, live stock judging contests, trips through the Experiment Station grounds, camp fires, classes for both boys and girls, and the big club parade on Farmers' Round-Up Day. The College, through the officials at the Station, co-operated in supplying camping facilities, stock as prizes in the judging contests, etc.

Training Schools for club leaders were held at M. A. C. during Farmers' Week on Feb. 1, 2 and 3, 1922. To this school came 36 club agents and local leaders. Mr. Ivan L. Hobson of the Washington office added much to the success of this meeting.

The Seventh Annual Training School was again held at the College on June 26 to 30, 1922. Club Agents and prospective club leaders from both the upper and lower peninsulas enrolled. This combined training school and conference has become one of the outstanding gatherings of club leaders from throughout Michigan.

Through the co-operation of the Department of Public Instruction, training schools for prospective club leaders were held in the county normal training classes in Mason, Allegan, Barry, Arenac, Lenawee, Calhoun, Gladwin, Eaton, Ontonagon, Cheboygan, Clinton, Ingham, Genesee and Saginaw counties, and at the Teachers' College at Detroit. In these schools 307 prospective club leaders received training for their work.

STATISTICAL SUMMARY OF RESULTS.

Project.	Number of clubs.	Enrollment.	Number of members reporting.	Value of products.
Corn	22	126	94	$3,188 60
Potato	18	97	69	3,191 67
Garden	199	6,667	3,578	30,823 87
Pig (breeding)	71	621	501	20,819 87
Sow and litter	18	97	60	9,160 70
Dairy calf	12	136	102	13,719 00
Dairy heifer	6	64	58	8,767 48
Cow and calf	1	12	11	4,865 00
Baby beef	2	52	37	3,328 28
Sheep	4	40	38	2,120 20
Poultry	51	501	303	8,294 26
Canning	104	1,744	1,307	28,859 56
Meal preparation	10	105	70	1,106 60
Clothing	296	3,174	2,213	11,700 46
Own Your Own Room	3	23	23	62 00
Handicraft	175	1,667	966	5,569 90
Bean	4	49	27	1,029 65
Hot lunch	168	3,336	2,170	5,614 58
Totals	1,164	18,511	11,627	162,221 68

REPORT OF COUNTY AGRRCULTURAL AGENTS

BY THE DIRECTOR IN ABSENCE OF STATE LEADER.

The data available for this report covers the year ending November 30, 1921, and is taken from the annual reports of the county agricultural agents which were submitted to the United States Department of Agriculture on that date. The position of County Agent Leader was vacant during a part of the year. Consequently, the greater part of the leadership in the making of plans of work in the various counties has been given by the various subject matter specialists. Necessarily, this situation has resulted in an unbalanced program in some cases, the emphasis being in proportion to the energy and aggressiveness of the specialists rather than in accordance with the importance of the projects.

The state program of work in agriculture carried out through the county agents is a result of year by year development. Each year may add new details and projects or abandon old lines of work. Emphasis may change from one project to another or from one view point to another according to financial conditions or other influences. The most actuating influence is the general feeling and opinion among farmers which is felt through their demand for service along one line or another and their lack of interest shown toward others. General demand and public opinion are moulded in a measure toward broad policies which are felt to be sound and important to the ultimate welfare of agriculture and rural life.

The most pronounced element entering into the agricultural program was the development of co-operative marketing machinery. The building up of commodity co-operative exchanges for the important industries of the State was the goal set for the year. In close association with this movement and greatly aided by it was a program of production based on standardized articles. The general policy of elimination of waste in production and distribution has been made effective in all projects.

These policies have been felt out on a state-wide basis through district conferences of agents who bring with them a consciousness of the needs and wishes of the residents of their areas. Definite expression of the major policies was presented to the annual meeting of the State Farm Bureau and recognition and support was given to at least the program of market organization.

In the execution of this organization program, the State Farm Bureau has co-operated fully with the Extension Service in building up the local units and federating them into commodity exchanges. This co-operation consisted in full discussion of each step in the plans, assistance in organizing local co-operative units and finally assuming of the responsibility by the State Farm Bureau for the calling of state-wide meetings of representatives of locals for purposes of federation.

As local co-operative units grow in number and strength, their influence in working out programs and plans of work is being felt through the County Farm Bureaus. The County Executive Committees of the Farm Bureaus are in such matters sensitive to the needs and wishes of the local marketing associations because it is often through these locals that the actual work is accomplished. In many counties marketing locals are being given representation on the county farm bureau committees.

The county farm bureaus of Michigan have abandoned business activities and have become, with few exceptions, purely educational organizations for carrying on promotional work in the interests of agriculture and home life in the country. The executive committee of each bureau is the extension committee through which the county agricultural agent with the assistance of state leaders works out the plan and program of work for the county. The execution of the program is accomplished through a number of methods. The period of development through which county farm bureaus have passed has caused lack of uniformity in organization. Many bureaus are still dependent upon the township unit system for representation. This plan merely serves to elect delegates once a year to a county meeting for purposes of electing officers, executive committee and giving general advice on program of work. In such bureaus, the executive committee is in full power throughout the year to direct program and plans. Other bureaus are formed on the basis of representation selected by local co-operative marketing institutions. This is proving more satisfactory because the local economic institution is permanent and represents the great majority of the people. The business local also has associated with it the strong leaders of the area and gives the whole bureau a setting of power and stability. It must be emphasized, however, that county farm bureaus controlled by representation from business institutions are educational in character and function as an extension machine. The service which the central county bureau extends to the business locals is entirely eduational and not one of business control.

It is anticipated that the number of counties employing agents in 1922 will increase to 67 or 68. No counties now in operation are likely to be discontinued for any length of time. Salaries of agents will decrease, but not seriously enough to lose good agents. The apparent trend of emphasis will swing toward production, not because of lack of interest in organized marketing, but because organized farmers will feel the need for standardized quality products and also because the experience gained through being organized and feeling responsibility and some power of action is stimulating progressiveness and thoughtfulness.

Statistical Summary of County Agricultural Agent Activities.

30 counties report 85 drainage systems planned, draining 21,556 acres.
52 counties report 23,979 farmers using 27,737 tons of commercial fertilizer.
46 counties report 3060 farmers using 58,757 tons of limestone.
35 counties report 5768 farmers treating seed wheat.
36 counties report 6365 farmers treating seed oats.
45 counties report 3799 farmers treating seed potatoes.
54 counties report 3814 farms on which alfalfa was introduced.
55 counties report 2417 farms on which sweet clover was introduced.
31 counties report 8617 farms using 724.485 pounds of poison for insect control.
29 counties report 5633 farms on which fruit trees were pruned.
32 counties report 5700 farms on which fruit trees were sprayed.
45 counties report 378 registered bulls secured.
12 counties report 14 cow testing ass'ns were formed in 1921.
27 counties report 266 silos erected.
34 counties report 69,300 animals tested for T. B.
19 counties report 23,973 hogs vaccinated for cholera.
14 counties report 66 farmers assisted in control of abortion.
22 counties report 210 farms introduced bees.
24 counties report 49 live stock shipping ass'ns with a membership of 1020 organized.
51 counties report 1039 farm account books distributed.
10 counties report 10 farm loan ass'ns formed.
59 counties report 510 co-op. buying & selling ass'ns formed, with a total business of $28,318,502.
20 counties report 68 water systems planned and installed.
29 counties report 89 sewage systems planned and installed.
16 counties report 54 lighting systems planned and installed.
61 counties report 22507 farm visits made.
61 counties report 412,748 people attending meetings.
61 counties report 42 counties publishing a paper regularly.

REPORT OF CLOTHING SPECIALIST.

BY HELEN ARMS.

The clothing work in Michigan during the past year has consisted of two principle projects: that of the dress form which has carried over from last year as strong as ever, and the millinery work which has grown very rapidly and become most popular.

The dress form work has been carried into sixteen counties this year following the same plan of organization of last year, i. e., local leaders from different communities in the counties were taught how to make the dress form, these women in turn went back to their own communities and taught other women. In this way it has spread more rapidly and reached many more people. At least three thousand dress forms have been made this year. The women have placed a value of at least $10 on the dress forms, making the total value of $30,000.

Thirty-four local leader millinery groups have been held this year. These have also been worked out on the same plan as the dress form meetings. Local leaders have been trained to carry on the work. The work has consisted of making new hats as well as the renovating of old hats. At these training schools 217 hats were made with a saving of $601.16. Definite reports have not come in as yet from many of the local leaders as to the number having been made in the different communities, although one leader did report twenty hats made.

From one community the report came back that the women are now wearing the best looking hats they ever had and with less expense. Special training work in millinery was given the home demonstration agents at their conference in January by the Specialist. Since that time nearly every home demonstration agent has carried on the work in her county as a main project. Many talks and demonstrations have been given by the Specialist on clothing topics such as textiles, color and line, alteration of patterns, etc., especially in the counties without home demonstration agents.

During Farmers' Week in February an exhibit of children's clothing was put on each afternoon by the Specialist in co-operation with the Household Arts Department. An exhibit was also selected and prepared for the mid-winter meeting in Menominee.

Every home demonstration agent has endeavored this year to spread the work in her county more efficiently and more effectively through the efforts of trained local leaders. Many more meetings have been held by the State Specialist for the purpose of training local leaders than ever before. The women are beginning to understand why it is necessary to carry on the work through local leaders, and there has been some rivalry as to who would be elected by the local people to go for such training. It is now considered an honor and a privilege to be sent to such a meeting for advanced work.

REPORT OF EXTENSION WORK IN DAIRY HUSBANDRY.

BY J. A. WALDRON, A. C. BALTZER, H. E. DENNISON.

Dairy extension work during the past year has been carried forward along somewhat different lines than in the past. In addition to the regular work of organizing and supervising cow testing associations, a purebred sire train was operated during August in co-operation with the Michigan Holstein-Friesian Association, and the Michigan Central and Pennsylvania Railroads. Intensive county dairy and alfalfa campaigns were also put on during the winter in place of the extension schools formerly held. These campaigns have proved very effective and the concentrated effort put forth in this way has resulted in a number of new cow testing associations with prospects for more, as well as for a number of co-operative bull associations. It is felt that these associations bring home to the farmer the principles of better dairying in a way that assures their daily application. The purpose is not increased production, but more efficient production.

More help has been given this project than in the past. A. C. Baltzer and J. A. Waldron have been employed full time, except for four months during the winter when the latter was unable to do field work because of ill health. H. E. Dennison has been giving full time to the project since December 1st and Prof. O. E. Reed and S. J. Brownwell of the Dairy Department have given especially valuable help at several different short periods during the year.

July 1st, 1921 there were eleven co-operative cow testing associations in Michigan with a membership of 235 farmers owning 2785 cows.

Sixteen co-operative cow testing associations were operating in Michigan July 1st, 1922 and were as follows:

Livingston County Co-operative Cow Testing Association.
Lapeer County Co-operative Cow Testing Association.
Western Allegan Co-operative Cow Testing Association.
Wayland Co-operative Cow Testing Association.
Wayne Co-operative Cow Testing Association.
Northern Van Buren Co-operative Cow Testing Association.
Oceana Co-operative Cow Testing Association.
Kent Co-operative Cow Testing Association.
Newaygo Co-operative Cow Testing Association.
Parma (Jackson) Co-operative Cow Testing Association
South Van Buren Co-operative Cow Testing Association.
Emmet Co-operative Cow Testing Association.
Kalamazoo Co-operative Cow Testing Association.
Eaton Co-operative Cow Testing Association.
Calhoun Co-operative Cow Testing Association.
Rives (Jackson) Co-operative Cow Testing Association.

There were in these sixteen associations July 1, 1922, 379 members owning 3989 cows.

In addition to the sixteen associations already operating there are four others organized that will be started within a month or as soon as competent testers can be found. These are located in Macomb, Calhoun, Berrien and one in Kalkaska and Antrim counties. A number of other counties are organizing associations so that there will undoubtedly be a material increase during the year. The increase may be limited somewhat by the lack of well trained competent testers.

Considerable interest has been manifested in co-operative bull association work. Bulls were purchased co-operatively in several cases along the route of the Better Sire Train on which pure-bred Holstein bulls were carried for sale and exchange. Groups of men in several counties have bought sires co-operatively during the year. No association of three or more bulls has been organized. Interest in this work is such, however, that several may be organized during the next year.

It would have been impossible during the past year, as at all times in the past, to have carried on the dairy extension work without the loyal support of the County Agents. This has been especially true during the past year in putting on the Better Sire Train and the Dairy and Alfalfa campaigns. Also as the number of cow testing and bull associations increases in the future, as in the past, the existence and successful operation of these associations will be due in a large part to the loyal support and timely aid of the County Agents in the counties in which they are located.

The following table gives a brief summary of the field work in Dairy Extension from July 1st, 1921 to July 1st, 1922.

	Meetings attended.	Attendance.	Meetings addressed.	Attendance at meetings addressed.
Conventions—State:				
Local—Cow Testing Association	16	472	16	412
Local—Bull Association	6	183	6	183
Local—Breeder's and Dairymen's Association	12	545	11	485
Local—Creamery	2	275	2	295
Local—Farm Bureau	2	40		
Local—Market Milk	1	75	2	45
Local—General Farmers and Business Men				
Better Sire Train	55	14,524	55	14,524
Dairy and Alfalfa Campaigns	634	12,808	634	12,808
Demonstrations—Judging	387	4,400	384	4,400
Exhibits—State Fair	1			
Local—Boys' and Girls' Club	1	75	1	75
Local—Community				
Conferences—County Club Leaders				
Conferences—Cow Testers				
Dairy Tours	4	50	4	50
Farm Visits	200			
Exhibits—Dairy Conventions	228			
Demonstration—Babcock Test	1	75	1	75
Total	1,550	33,552	1,116	33,352

REPORT OF EXTENSION WORK IN DAIRY MANUFACTURES.

BY H. C. JORDAN.

Extended efforts will be necessary among cheese makers of the State to educate them to the need of making better quality American or Cheddar cheese. Cheese made at the present time, especially in the Lower Peninsula of the State, is entirely too moist and spongy to be a safe article of commerce and cannot be cured properly without developing bad flavors and weak body.

Forty-eight factories were visited (since March 1) and individual instructions given to forty-eight cheese makers to improve the quality of cheese by eliminating excess moisture, the use of pure lactic cultures recommended to overcome gas producers and other undesirable bacteria.

Moisture tests of cheese have been made so far at twenty factories to determine the relation of moisture to the general quality of cheese. This work will continue with a view to educating cheese makers to produce firmer cheese, instruct them in the use of the moisture test, and, finally, limit the moisture content of cheese by law.

Work for the present must necessarily be confined to getting cheese makers to realize the need for improvement in the quality of their product. To some extent, this has been accomplished, but competition between milk buyers is keen, and the temptation of increasing yield by incorporating an excessive amount of moisture will probably have to be stopped by law, limiting moisture in cheese by legislation.

Work will continue along these lines during the coming year, and efforts will be made to obtain co-operation of cheese dealers to get proper grading of the cheese and pay for them according to quality.

This work has been conducted with 28 factories.

REPORT OF EXTENSION WORK IN ENTOMOLOGY.

BY R. M. HAIN.

The month of July was spent in the Upper Peninsula in demonstration of the use of poison baits in the control of grasshoppers. These insects were very bad at that time, many farmers even lost their hay crops. This work was continued into the fore part of August, the time being spent largely in the field.

The grape district around Lawton and Paw Paw was then visited to follow up the measures taken earlier in the season against the grape leafhopper and grape berry moth, noting the success of the treatments that had been applied earlier in the season.

The demonstration of a repellant against the flat headed apple tree borer was taken up at that time and applications made.

During September and October some time was spent in the giving of advice against the Hessian fly in the field and a demonstration of paradichlorobenzene was started against the peach tree borer. This treatment for peach tree borers seems to be successful so far as one can judge at the present time.

Some time was also spent during this period in the corn fields of Wayne county in carrying on an educational campaign against the European corn borer.

The first two weeks in September were spent in preparing for and attended the State Fair at Detroit, where an effort was made to exhibit noxious insects and to demonstrate their control.

Later a trip was made through part of the northern part of the Lower Peninsula to collect information on the recent grasshopper outbreak and to confer with the County Agents on any insect troubles they might have.

After this the time has been occupied with the winter meetings and talking on insect control up to April 1, 1922. These meetings were well attended in all cases.

REPORT OF EXTENSION WORK IN FARM CROPS.

BY J. F. COX, PROF. OF FARM CROPS; G. W. PUTNAM, SPECIALIST; H. C. RATHER, SPECIALIST; D. F. RAINEY, SPECIALIST.

The demand for extension work has increased to the extent that it is not possible to meet all requests for service with the staff available. The careful development of leading projects has, we believe, led towards greater efficiency in work performed.

Mr. G. W. Putnam was placed in charge of the general crops extension projects April 1, being transferred from the position of Crops Experimenter, assigned to the Upper Peninsula. The alfalfa and legume campaigns begun last fall have occupied a large part of his time. Mr. Putnam is also in charge of the direction of the field inspection work of the Michigan Crop Improvement Association, and the release of new varieties from the College increase plats.

With the resignation of Mr. A. L. Bibbins, January 1, 1922, to become Manager of the Seed Dept. of the Grange League Federation Exchange of Syracuse, N. Y., Mr. H. C. Rather was elected Secretary of the Michigan Crop Improvement Association and placed in charge of the crops varietal standardization project. The close co-operation with the Farm Bureau Seed Department has greatly increased the influence of the Crop Improvement Association.

Crop demonstrations and varietal tests, handled by Mr. D. F. Rainey, have proved to be of great value in aiding in the dissemination of crop varieties according to adaptations. In many counties, the alfalfa campaign work is made particularly effective, due to the presence of carefully planned alfalfa demonstrations planted one or two years before.

The demand for crop exhibits at County Fairs, the State Fair, and the International Grain and Hay Show, required considerable preparation along that line. Mr. H. C. Rather, assisted by members of the Farm Crops Department, handled this work.

Alfalfa and Legume Campaign.

Owing to the success which alfalfa growers have met with during recent years, and from the standpoint of permanent soil benefit, and the livestock situation in Michigan, it was deemed advisable to greatly increase the acreage of alfalfa. In most localities alfalfa is a "key crop". Not only is the growing of this crop directly profitable, but the indirect benefits are very great. The successful production of alfalfa necessitates liming, the use of phosphate, etc., and leaves the land in excellent condition for growing general crops. It is also of great value in cheapening and bettering livestock feeding rations.

A state-wide alfalfa campaign was announced in August 1921. The work was placed on a county basis being conducted either in co-operation with the Dairy Department as a "milk and alfalfa" or as a straight "legume" campaign. The "milk and alfalfa" campaign, beginning October 29 to November 5, held in Allegan county, was led by two teams, each composed of one man from the Farm Crops Department and one from the Dairy Department, each making four meetings per day with one night meeting. The meetings were held in barns during the day-time and in grange halls and other campaign meeting places at night. Over two thousand four hundred farmers attended these meetings and it was estimated that the alfalfa acreage in Allegan county had increased to three thousand acres—over 70% during the past spring.

Alfalfa "campaigns" were conducted in eighteen counties, though practically all county agents encouraged the extension of the alfalfa and legume acreage as a main project. Apparently, the alfalfa acreage has increased to the extent of two hundred and seventy-five thousand acres during the past year. Most of the farmers estimate that successful growing of alfalfa on land will increase its value from twenty to forty per cent. Allowing an increase of $10 per acre in land valuation, it is not unreasonable to believe that the increased plantings of alfalfa will benefit the State by at least $2,000,000 due to the added land valuation. The great increase is in added profits equal to at least one ton of extra hay per acre worth from $10 to $15 per ton, or an additional two million dollars or more.

The chief benefits of alfalfa come through direct profit from the crop and more economical feeding of livestock. It is reasonable to believe that an increase of over two hundred thousand acres, placing the alfalfa acreage of Michigan over five hundred thousand acres, will result within a year in added returns of from four to eight million dollars, with increasing future returns due to increased amounts of livestock carried per farm, increased milk production and increased yields of the crops following alfalfa. The establishment of a successful stand of alfalfa pays not only immediate profits, but substantial dividends distributed over many years.

Proper methods of establishing successful stands of clover, red clover, alsike, mammoth, and the value of other legumes, such as vetch and soybeans, were emphasized in regions where these crops are needed and adapted. Legume campaigns will be conducted during the coming year in the potato, bean, sugar beet, canning crop producing counties and livestock counties. All members of the Farm Crops Department, in addition to the regular Extension men, are aiding in the alfalfa work.

The immediate success of alfalfa and better clover campaigns were made possible, largely due to the excellent seed supplied in quantity from dependable sources by the Farm Bureau Seed Department. Over two hundred and eighty thousand pounds of Grimm alfalfa and approximately three hundred thousand pounds of northern grown common have been distributed in Michigan. Home-grown alfalfa seed played an important part in increasing the acreage in many counties under favorable seed producing conditions of last year. Over 150,000 pounds of Michigan grown alfalfa seed was used in Michigan, the first time that home-grown seed was of importance.

CROP VARIETAL STANDARDIZATION.

Mr. H. C. Rather reports as follows:

The work of crop improvement in Michigan is carried on in close co-operation with the Michigan Crop Improvement Association, the Seed Department of the Michigan State Farm Bureau, and County Agricultural Agents and their supporting organizations. During the past year, there have been held demonstrations in seed production, selection and improvement with more than 300 farmers. Along with these demonstrations there has been given information concerning proper cultural practices, treatment for disease, and various other matters relating to crop production which make for greater efficiency and economy in this phase of agriculture.

Seventy-five of these co-operators successfully met the pedigreed seed requirements of the Michigan Crop Improvement Association and thereby made available 10,000 bushels of Rosen, 6,500 bushels of wheat, 14,000 bushels of oats, 2,000 bushels of barley, 3,000 bushels of beans, 1,000 bushels of soy-beans, and 1,500 bushels of corn, grown from improved varieties developed or approved by the Michigan Agricultural College, practically all of which was used for seed purposes. In addition, thousands of bushels of seed of these varieties, but a generation or so removed from certified seed, were planted and are exerting a potent influence for a more profitable crop production.

A mailing list of 700 including farmers, county agricultural agents, elevator and seed houses, received from this department during the year six news-letters, eight printed circulars along with other matter relative to seed improvement. The circulars have a wide dissemination other than the regular mailing list and 5,000 copies of each were sent out.

The message of better seeds was carried to visitors at county fairs all over Michigan. Standard exhibits on improved varieties, weed control and other seed topics were furnished to thirty-eight county fairs by routing them over five different circuits and a larger and more comprehensive exhibit, attended by crops specialists, was shown at the Western Michigan Fair at Grand Rapids and the Michigan State Fair at Detroit.

An exhibit extending over 68 feet of wall space and showing the co-operation of the Michigan Agricultural College and the Michigan Crop Improvement Association in the development and dissemination of improved crops varieties was shown at the International Grain and Hay Show in Chicago. Michigan farmers themselves, most of whom had received instruction in the production and preparation of quality seed from extension workers in this department, made numerous entries at this show with gratifying success particularly in the rye class where 25 out of the 30 awards went to farmers in Michigan.

The annual Seed Show of the Michigan Crop Improvement Association held during Farmers' Week at the Michigan Agricultural College brought out keen competition and served to refix in the minds of growers the standards that make for efficient quality production.

PROGRESS OF WORK IN THE INTRODUCTION AND INSPECTION OF VARIETIES—REPORTED BY MR. G. W. PUTNAM.

The following improved varieties were released from the Experiment Station increase plats:

There has been distributed seven hundred pounds of elite stock seed of Improved Robust beans to twenty-nine growers for increase and trial. Twenty-one bushels of elite stock seed of Duncan corn has been released to twenty-one growers, eleven bushels of M. A. C. Yellow Dent to twelve growers, eleven bushels of Golden Glow to twelve growers and in addition several bushels of these three varieties of corn were released through the Michigan State Farm Bureau Seed Department. Twenty pounds of the new Hardigan alfalfa was distributed to twenty-six growers.

In the release of this elite stock seed of these various varieties careful arrangements have been made to have it inspected to maintain its identity.

A new system has been put into practice which follows the suggestions of the International Crop Improvement Association, which was reported at their third annual meeting at Chicago.

The new system recognizes that there should be three classes of seed, elite, registered and certified. The elite and registered will be the source of seed for seed production while the certified will be the source of seed for crop production. By this system it is hoped to be able to give the farms of Michigan and adjoining states a source of seed of superior quality and at a reasonable price.

Applications for inspection on 165 farms have been received to date for pedigreed grain, distributed as follows:

Rosen Rye	59
Red Rock Wheat	15
American Banner Wheat	5
Wolverine Oats	36
Worthy Oats	17
College Wonder Oats	11
College Success	1
Iowa 103 Oats	2
Wisconsin Pedigree Barley	10
Black Barbless Barley	7
Winter Barley	2

Applications for corn, beans, soybeans, Hubam clover and Hardigan alfalfa have not yet been received, but should total over one hundred and twenty-five.

REPORT OF CO-OPERATIVE VARIETY DEMONSTRATIONS.

BY D. F. RAINEY.

Perhaps of greatest importance is the establishment of alfalfa variety demonstrations of which eleven have been planted and six more are to be planted this year. These serve a double purpose, first, showing the value of the variegated varieties over common strains, and second, the methods of obtaining successful stands of alfalfa.

To aid the farmers of Michigan to determine what place Hubam clover may occupy in our farming practices, 375 pounds of Hubam was distributed in 15 pound lots. Usually, an equal amount of Biennial White Blossom sweet clover was sent so that the growth of the two clovers could be compared when growing under similar conditions.

Eight counties have soybean variety demonstrations, containing seven leading varieties, planted this year, the object of such demonstrations being to determine the highest forage yielding varieties for different sections. Many farmers are unfamiliar with the different varieties and their habit of growth and these demonstrations furnish the farmer an opportunity to see some of the varieties growing side by side.

The Robust field bean, which has consistently proved the highest yielding variety at the Experiment Station, is used as a check in the three counties conducting field bean variety demonstrations. In the past, the Robust has almost invariably out-yielded all other varieties including those grown locally.

In two counties we have oat and barley demonstrations. These demonstrations include the best developed by the College, as well as those being grown locally. The pedigreed varieties have proved to be the highest yielding ones.

There are five wheat variety demonstrations to be harvested this year. These demonstrations include some of the best known wheats of Michigan and Ohio, as well as local varieties, and new ones recently developed by the Experiment Station. These demonstrations are expected to determine the adaptation of varieties to different localities.

Attached herewith is a map showing locations of these demonstrations.

Farm visits	305
Lecture meetings	198
Attendance at lecture meetings	3854

During the coming year the legume campaign work will be continued in counties which have not as yet been reached. The main projects herewith outlined will be followed through along similar lines. We expect to devote more attention than usual to corn improvement by increasing the supply of high quality seed of the best yielding varieties.

The number of inquiries received from farmers by mail relating to crops question has greatly increased. Eleven thousand four hundred and eighty first class letters were written by Experiment Station and College workers in the Farm Crops Dept. and eight thousand, four hundred and seventy-five first class letters by Extension men in Crops, or a total of nineteen thousand, nine hundred and sixty-one letters in answer to crops inquiries. In addition, a large number of inquiries were answered by appropriate bulletins or circulars.

The Extension Specialists in Farm Crops and members of the Crops Department who are co-operating with them, highly appreciate the help and co-operation of the members of the Extension Division and of the County Agricultural Agents.

REPORT OF EXTENSION WORK IN FARM MANAGEMENT.

BY H. B. KILLOUGH.

Farm management demonstration work for the past year has been directed along three principal lines: Farm accounting, farm credits, price movements as they affect agriculture.

Farm Accounting:

Twelve hundred and twenty-five farm account books have been sold to farmers since July 1, 1921. Indiscriminate sale of books to farmers who were unlikely to use them has been avoided in so far as possible.

Farm accounting courses have been introduced into ten Smith-Hughes Schools. The method of having farm boys and girls use for laboratory exercises accounts which they keep on their own home farms, is growing in popularity.

Follow-up work in farm accounting has been conducted through the mail and by personal visits.

Farm Credits:

Farmers, county agricultural agents and bankers have been furnished with facts to show farm credit needs and returns from the several classes of farm investments and expenditures. The facts were obtained from cost accounting routes conducted by the Experiment Station from farm records kept by farmers in co-operation with the College and from farm management surveys. A survey was made in connection with farm accounting schools covering approximately 465 farms in fifteen counties.

Price Movements as they affect agriculture:

During the fall and winter months a regular service dealing with price trends and factors which influence price movements was sent to all county agricultural agents. This service seemed to meet with general approval. One hundred and sixteen applications from farmers who wish to be placed on the Washington mailing list for Crop and Market Reports have gone through this office.

Publicity:

Ten general news articles and eight stories for farm papers of the State have been published besides publicity material sent to the various counties for farm bureau bulletins and in addition to exhibits prepared for the State Fair, Annual meeting of the State Grange, Farmers' Day and Farmers' Short Course at the College.

At the present time, a series of pamphlets is being prepared in co-operation with the Experiment Station force of the Farm Management Department and other departments, for farmers and others who are seeking agricultural opportunities and who are interested in concise summaries of the financial transactions and economics of various types of farming practiced in Michigan.

REPORT OF HOME DEMONSTRATION WORK.

BY LOUISE H. CAMPBELL.

Three counties have been added to home demonstration organization during the past year: Marquette, Saginaw, and Gladwin. The women in Houghton, Schoolcraft and Menominee counties voted in May at their county-wide home demonstration meetings to ask the Board of Supervisors in October for an appropriation to reinstate the work in their respective counties. The county Board of Supervisors in Dickinson and Chippewa counties voted to discontinue the work, because of financial conditions. The women of Dickinson county, however, are going before the Board of Supervisors in June, and hope to have the work reinstated by July first.

Organization for work in home and community

The organization is carried on similarly to that of last year. In counties having home demonstration agents, each township or community has a committee composed of a chairman and four others. The chairman of this committee is to be elected by the women of the township or community and she selects the other members of the committee for her township. The chairmen of the various township committees at the time of their annual meeting, select three or five of their members to act as a county executive committee of home demonstration work. The chairman of this committee serves in many of the counties as a member of the executive committee of the County Farm Bureau.

Every home demonstration agent is endeavoring to strengthen the county organization work and to encourage the women to greater activity in home demonstration work, and as a result the women this past year have become more and more interested in local leader training meetings and are electing their county, community, or local project leaders for the various types of work which they have chosen for their program. The women have sent in more reports than formerly, and their response has been most gratifying.

Home demonstration work has been brought before the public through lectures, demonstrations, exhibits, newspapers, Farm Bureau News Letters, and the local leaders themselves.

A state-wide conference of agents and specialists was held in January. "Subject matter" was stressed at this meeting. Two district conferences were held at which "methods" were discussed. Miss Grace E. Frysinger of Washington, D. C. spent a week at the College at the southern peninsula district conference. Much benefit was derived from these Conferences, The State Leader feels that a great deal has been done this past year to stabilize the work. The women are more persistent in their demands for the assistance from the state officers and for assistance in organizing the county in securing the services of a home demonstration agent.

Special attention has been given to publicity and articles have been written for the Michigan Farmer, Lansing State Journal, and Farm Bureau News Letters. Attractive posters have been made by the school children in schools where the nutrition series has been given.

Special co-operation in nutritional work has been given by the county agents, public health and Red Cross Nurses, school teachers, editors, ministers, the Grange, women's clubs, and local community clubs.

Nutrition

Nutrition work this past year has been carried on through food study groups, individual home demonstrations, children's clinics, nutrition series, lectures, lecture-demonstrations and exhibits.

The home demonstration agents have organized and worked with many more nutrition groups than last year. The women are becoming greatly interested in the scientific feeding of their families. Several of the agents have worked with the children through home demonstrations. The mothers of the children have closely followed the advice of the home demonstration agents or State Nutrition Specialist. The work with the school children has been a great success. The parents of the children have become intensely interested in the nutritional stories. One of the county nurses in an unorganized county wrote as follows of the work carried on in one of the district schools: "I found them using your nutrition stories enthusiastically, where the 'story day' was a village event, long looked forward to, the mothers going whenever possible."

Instruction has been given in the selection, preparation, and care of foods, planning of meals and diet for special diseases. There have been so many calls for diets for obesity that the nutrition specialist wrote a circular on that particular subject for distribution.

Eight nutrition stories were written by the nutrition specialist. Record charts were prepared and sent out with stories to the local leaders or teachers. The County School Commissioner of Gladwin county stated this spring that the scholarship in the schools of that county had increased 25%.

Clothing

There has been a decided change in the type of assistance rendered by the Specialist. Fewer talks and demonstrations have been given before groups of women, and more help has been given the home demonstration agents in the presentation of subject matter and illustrative material. A greater number of local leaders have been trained, and, as a result, more home demonstrations have been established than ever before.

The dress form project has been featured again this year through popular demand, and has not only proven a worth while project to assist the women in fitting their garments, but has been responsible for developing the health side of clothing work and also has helped to strengthen home demonstration work in community and county as well.

There is still a demand for lecture demonstrations on selection of textiles and clothing. These demonstrations have covered color, line, and materials. Practical household tests for fabrics have also been taught. The subject of proper footwear has been popular and when the subject was presented it was usually strengthened by an exhibit of the proper types of shoes from the nearest shops.

Millinery work is growing. Thirty-four millinery training group meetings have been held during the year. The work has consisted of making new hats as well as renovating of old hats. Requests have been made for training in both spring and fall millinery.

The women who have made dress forms are now eagerly asking for aid in dressmaking. This, undoubtedly, will be one of the foremost projects this coming year.

The Clothing Specialist assisted with the exhibit at the State Fair at Detroit, and during Farmers' Week co-operated with the Household Arts Department, in putting on an exhibit of children's clothing in the Home Economics Building.

The work has been given publicity through local leaders, newspapers, county Farm Bureau News Letters, Michigan Farmer, women's clubs, and the Grange. A great many clothing bulletins and circulars have been sent out into the State from the Home Economics Extension Department.

The value of the clothing is evidenced by the number and quality of reports made by the local leaders, and also from those unsolicited reports. One woman reported as follows: "I have made a dress since I have my dress form and certainly think it is just fine. I would not get along without one now that I know what they are."

Household Management

The household management work the past year has consisted of:

1. Home accounts and especially in connection with this, getting the housewife to realize the importance of the money value of the food coming from the farm. Some over thirty who are keeping these accounts handed them into this office giving the department some very valuable information in regard to the amount of food which the average farm family gets from the farm and the value of the same. Judging from the number of account books ordered during the year there has been a decided gain in the number who are keeping accounts.

2. Better arranged kitchens. The Specialist has assisted in rearranging about twenty-five farm kitchens this year. The arrangement of kitchens for convenience and better equipment and more home conveniences has been emphasized throughout the year at all types of meetings.

Local leader meetings were held in three counties at which time the women discussed the conditions in their counties and made plans for making a survey. An article was written for one of the state papers explaining how a kitchen might be put on by local committees at county fairs, and the Specialist met with three committees to help them plan such an exhibit. A series of articles was written on household management for the County Farm Bureau Bulletins.

The most splendid co-operation has been had during the past year with the Farm Managament Department and the Farm Mechanics Department. They have been of great assistance in working out different problems.

REPORT OF HOUSEHOLD MANAGEMENT SPECIALIST.

BY EDNA V. SMITH.

The object of this project during the past year has been two fold:

1. To bring to the farm women of Michigan more of a realization of the money value of the food which is obtained from the farm, as well as the advantages of having expenditures well planned in advance.

2. To lighten the housework through more home conveniences and better arranged kitchens so the farm wife as well as the rest of the family will get more enjoyment from living on the farm.

One hundred sixteen farm women started keeping home accounts in study groups last year. Thirty-six of these women finished the year's work in good shape, giving us some very valuable data. The results of this work done by the women was tabulated and presented at the State Grange meeting in December. Since that time it has been presented to 22 groups such as granges, farmers' clubs, farm bureau meetings, etc. Only recently one man remarked at a meeting that he would have given anything had his wife been present and heard the talk because she had become very blue and discouraged with their income from the farm the past year.

At least 500 of our home account books have been sold during this year showing a decided growth in the number of women who are keeping accounts.

The rearrangement and remodeling of kitchens to make them more convenient has been emphasized this year. This has been through group meetings, local leader meetings, and with individuals. The Specialist has assisted in the planning of 23 kitchens.

Five meetings have been held with the leaders of different communities of Kalamazoo, Wayne and Oakland counties at which time local conditions, the housewives' greatest problems with the possibilities of correcting them, were discussed. Local surveys were made as to number having running water in the home, the number having some type of lighting besides old kerosene lamps. Each woman was asked to score a kitchen for convenience and equipment.

Two meetings were held with committees in Barry and Lenawee counties who wanted to put on a model kitchen exhibit at their county fairs last fall. Walls, floor covering, furniture and equipment were discussed and selected.

At the annual round-up at Chatham, an exhibit of labor-saving devices was prepared and shown by the Specialist. It consisted of good cleaning brushes, good knives, good shaped cooking utensils, bread mixer, steam and pressure cooker, wheel trays, etc.

Besides a great many home-made fireless cookers, steam and pressure cookers, hundreds of small pieces of equipment like the stainless steel knives, dish drainers, plate scrapers, pan lifters, etc., have been put in homes as a direct result of talks given by the home demonstration agents and the Specialist.

A series of articles was written for the country Farm Bureau bulletins on different household management subjects.

REPORT OF NUTRITION SPECIALIST.

BY MURIEL HOPKINS.

The Nutrition Specialist began her duties in Michigan, September first. While the ultimate goal of her endeavors has been that of establishing better nutrition habits in the homes of Michigan through the medium of local leaders made up of representative women in rural communities, the department felt it necessary that people become acquainted with the policy for nutrition work and that the Specialist become acquainted with the habits and needs of the people of the State. For that reason, the program has been a long time one rather than that of reaching the goal in one year's time.

One hundred and fifty-nine general nutrition lectures have been given in thirty-six counties of the State, reaching 12,143 people. These lectures have proved a very good means of acquainting people with nutrition work and from the number of requests for help which have come to the office as a result, we must conclude that these lectures have been very worth while.

Nutrition exhibits have been planned and placed in two county fairs; State Federation of Women's Clubs; at the Home Economics Building at the College for Farmers' Week; for the Better Baby Week Campaign at Grand Rapids. Two weeks have been spent in conference with the state officers and home demonstration agents. One of these was a subject matter conference, the other a conference for working out plans for future work with Miss Grace E. Frysinger, Field Agent, Extension Methods in Organization, of Washington, D. C.

As a result of this latter Conference, the Nutrition Specialist has spent a great deal of time during May and June planning material for a set of nutrition leaflets. There are to be seven leaflets in the series as follows: (1) Feeding the baby until it is twelve months of age; (2) Feeding the baby during the second year; (3) Feeding the pre-school child; (4) Feeding the school child; (5) Diet for overweight; (6) Diet for underweight; (7) Diet for constipation. A home card is being planned for each leaflet which will enable the housewife to check up on desirable habits each day and will enable the Specialist to tabulate suggestions adopted.

The outstanding project in the nutrition work has been the nutrition series. Eight stories told in simple language were arranged. These stories each told a necessary nutrition habit to children, stressing two reasons why such a habit was most desirable. One story each month was sent to the rural teacher (in a few cases urban teacher) enrolled. Each story was accompanied with a roll call chart. The teacher told the story to the children, placed the chart on the wall where it stood as a constant reminder for one month of the nutrition habit which was being stressed for that month.

The results of the series have been most gratifying. A high percentage of teachers have sent in reports declaring that the series has not only helped in establishing definite nutrition habits but that there has been a marked gain on the part of children in physical condition, resistance to disease, improvement in scholarship, and in helpful spirit one to another.

The series has reached in part or in whole, forty-four counties, 1,941 schools, and 44,643 children. Since the series has been introduced during the entire school year, it has been impossible to complete it in every instance. The results stand as follows:

Children having formed daily milk drinking habit for one month. 52%.
Children having formed daily big breakfast habit for one month. 81%.
Children having formed daily habit of eating vegetables other than potatoes for one month. 58%.
Children having formed daily habit of sleeping at least ten hours for one month. 46%.
Children having formed daily habit of not eating knick-knacks between meals. 36%.
Children having formed daily habit of brushing teeth before going to bed. 41%.
Children having formed daily habit of eating a good serving of fruit. 43%.
Children having formed daily habit of eating a big breakfast, big, dinner, and big supper. 44%.

REPORT OF THE EXTENSION WORK IN HORTICULTURE.

BY T. A. FARRAND.

During the fiscal year there has been a remarkable increase of interest in fruit growing in practically all parts of the State, probably due to the financial success that has come with this line of production during the past few years. This is largely due to favorable conditions for fruit production which surround the State and a large nearby accessable marketing area.

With this increased interest there followed naturally a greatly increased demand for information as to sites, soil, insect and disease control, and cultural practices in relation to growing all kinds of fruit.

Acting as Secretary for the Michigan State Horticultural Society offered a splendid opportunity which was taken advantage of in getting in touch with the growers' problems through its members located in different parts of the State. Interest was quickly created in the Extension work and the College which has proved very beneficial to the extension service and the Society.

Following up the program of work as shown in the previous year's report, that is, a major project in fruit fertilization, co-operating with the Experiment Station, a large number of demonstrational tests were put on with the county agents, a few records of which will be given in this report with the result that in comparison with one hundred tons of fertilizer in the two previous years approximately twenty-five hundred tons were placed this year.

The following is a brief outline of some of the results secured with fertilizer this last year.

PEACH ORCHARD—EDWARD SKINNER, HARTFORD.

Treatment per tree.	Date of application.	Yield per tree, lbs.
3 lbs. nitrate of soda	April 12	68.15
3 lbs. nitrate of soda, 5lbs. acid phosphate	April 12	78.3
3 lbs. nitrate of soda, 5 lbs. acid phosphate, 2 lbs. muriate of potash	April 12	67.4
Check row		33.66

APPLE ORCHARD—M. S. RUSSELL, BANGOR, MICH.

Treatment per tree.	Date of application.	Yield per tree, bu.
5 lbs. nitrate of soda	April 12	16.7
5 lbs. nitrate of soda, 10 lbs. acid phosphate	April 12	13.9
5 lbs. nitrate of soda, 10 lbs. acid phosphate, 2 lbs. muriate of potash	April 12	15.2
Check row		10.9

CHERRY ORCHARD—WARD REYNOLDS, BENZONIA, MICH.

Treatment per tree.	Date of application.	Yield per tree, lbs.
3 lbs. nitrate of soda	April	14.5
3 lbs. nitrate of soda, 5 lbs. acid phosphate	April	19.5
3 lbs. nitrate of soda, 5 lbs. acid phosphate, 1½ lbs. muriate of potash	April	11
Check row		8.5

Orchard hit by frost consequently lower yields.

BLACK RASPBERRIES—BERRIEN COUNTY.

Complete fertilizer	67 quarts
Nitrogen and phosphorus	67 quarts
Nitrates alone	76½ quarts
Check	47½ quarts

The writer has been more or less familiar for years with soils and their condition and with the cultural practices in the fruit sections of Michigan, and has noted the general depletions taking place. The object of this strong fruit fertilization program has been to determine the most economical system of supplying the necessary plant food for the different kinds of fruits by feeding the cover crop and trees where that system is used, by supplementing stable or stock yard manures, with commercial fertilizers, when the supply of manure is low and prices are comparatively high.

The enthusiasm of a large number of growers with the results of the experiments and demonstrations would indicate that this project is very important to the future fruit interests of Michigan in producing more annual crops of larger and more uniform product.

Up to the present time with two years' work to draw conclusions from, nitrates in the form of either nitrate of soda or sulphate of ammonia has shown far more profitable results than either acid phosphate or potash. The records show in some instances phosphate showing results when combined with nitrates. The above statement applies to both fruits and cover crops.

For years in the past Michigan has been burdened with plantings of a hundred varieties of apples, a large percentage of which are of little or no value and it was considered high time that a standard list be adopted from which growers could choose those adaptable to Michigan climatic conditions; also that would be a foundation for standardization in grading and packing which is necessary in any successful marketing project.

Through efforts of the Horticultural Department, the Executive Board and Horticultural Committee of the Michigan State Horticultural Society the following list of varieties of apples were recommended as a standard list for Michigan, and as far as seemed practicable the varieties were named as to adaptability to different sections of the State:

Duchess, Wealthy, McIntosh, Fameuse, Jonothan, Grimes Golden, Wagener, Greening Rhode Island, Steele Red, Northern Spy, Hyslop Crab.

The above list was considered only for the large commercial sections and not for local markets.

Large numbers of meetings were asked for both lecture and field in relation to pruning, spraying and fertilization, all of which could not be cared for, although all the members of the Horticultural Staff assisted in the Extension service whenever possible.

With the pruning work we have endeavored to head off over-pruning on both old and young apple trees and suggest moderate pruning with special reference to young trees until such time as we have definite knowledge as to which system produces definite results.

Intercropping of young orchards is recommended as an economic system that will bring in some financial returns while the orchard is coming into bearing.

A conservative move is being fostered towards an alfalfa and apple combination with apparent splendid possibilities along this line.

Preliminary work has been started in a better cultural practice and a much more disease free nursery stock campaign which will take some time to work out. This was recommended after a two day tour in Van Buren and Berrien counties with Specialists from Washington, Horticultural Department and Botanical Department with a few growers and small fruit nurserymen.

There were 462 farm visits; twenty-five meetings held at demonstrations, with an attendance of 725 at such meetings. One hundred and nine lecture meetings were held with an attendance of 12,310 at the lectures.

REPORT OF THE DIRECTOR OF MARKETS.

The market extension work in Michigan, during the past year, has closely followed its project, which has extended over a period of four years. This work is not based on a patronizing attitude towards agriculture, but entirely on the theory that permanent assistance to agriculture can only be effected through the establishment of organization on a firm and self-supporting basis, carrying all responsibility. Special emphasis is also given to the sociological factors incident to the development and maintenance of local leadership, carrying full responsibility for marketing undertakings.

A cardinal feature of the organized agencies in Michigan among farmers is that organizations are aimed at the general efficiency of the industry. The undertakings in marketing must be on a basis of efficiency sufficient to meet legitimate competition, but if the whole undertaking is established on the basis of the savings between the co-operative system and the old regime many co-operative undertakings would be very questionable. The marketing function is the basis of common interest around which the co-operative institutions of farmers are merely built, but the efficiency in production, as well as efficiency in marketing and the still more difficult problems of co-ordinating production with demand is the larger aim of the organization work in Michigan.

The work during the year has been concentrated on giving assistance to Michigan fruit interests in the working out of a re-organization program and to the Michigan State Farm Bureau in working out a plan to co-ordinate the interests of the commodity exchanges in the State with the State Farm Bureau and also, later in the year, in assisting the Farm Bureau in the establishment of a Produce Marketing Department and to the undertaking of the Michigan Live-Stock Exchange in the establishment of commission houses in the principal receiving markets for Michigan live-stock. Assistance was also given to the American Farm Bureau Federation committee on fruit marketing. Work of a less important character was devoted to the assistance of the Michigan Potato Growers' Exchange and the Michigan Elevator Exchange.

Michigan Fruit Growers, Inc.:

In an effort to improve the general character of the fruit organizations a conference of representatives of all fruit organizations in the State was called by the Michigan State Farm Bureau. The primary purpose was to federate and unite the numerous local organizations that have grown up in the fruit belt in order to concentrate their efforts and mobilize their economic power. This meeting was followed by a series of meetings and conferences which resulted in the formulation of the plan for a state-wide-organization, known as "Michigan Fruit Growers, Inc." It was not thought feasible to attempt to put the organization in operation the present season on account of complications, due to contracts which some of the units had with commercial selling agencies. Work will be resumed on this project as soon as the active shipping season is passed, with the idea of completing the organization for next year's work.

The Federated Fruit Growers:

Two years ago the executive committee, through President Howard, of the American Farm Bureau Federation, appointed a committee of 21 to represent the organized fruit interests of America, to study the program of fruit marketing with a view to recommending a national plan. The Markets Department has been asked to assist in this work and the Director has attended two meetings of the Committee in Chicago and one in New York. A plan has been recommended and an organization completed. More recently this organization has made a contract to buy out the North American Fruit Exchange, a large commercial distributing agency, which had several important contracts with co-operative fruit organizations in Michigan. The elimination of these contracts should remove practically all obstacles to the completion of a state-wide fruit growers' association.

Michigan State Farm Bureau Produce Exchange:

In response to a general demand from farmers within the State, the Michigan State Farm Bureau has recently established a "Produce Exchange" as a department, with headquarters at Detroit. The reason for not organizing this as a separate exchange was that the produce to be handled is widely scattered and lacks concentrated volume, so that local organizations can with difficulty be built around this service, and as it is believed that local organizations are absolutely essential to the organization of commodity exchanges, it was thought that the general machinery of the State Farm Bureau would be more sensitive and adaptable to the will of the producers than a separate organization. The Produce Exchange is expected to operate very largely as a separate organization, entering into contract with the local established units of various character for the handling of eggs, butter, poultry products, small fruits and vegetables, but will not operate in competition with other commodity exchanges.

The Michigan Live-Stock Exchange:

Assistance to the Live-Stock Exchange, during the year 1922 has been principally on their problems of establishing co-operative commission houses at Detroit and Buffalo and the working out of a proper organization for such service. A commission house has already been established at Detroit which is at present the largest factor in the handling of live-stock on the Detroit market. Michigan has joined with the state farm bureaus of Ohio and Indiana in the establishment of a commission house at Buffalo. This house is to commence operations about the 1st of September. The Markets Department assisted in working out plans for this tri-state organization, which is to be associated with the National Producers' Association, a national farm bureau association devoted to the handling of live-stock from a larger viewpoint.

Michigan Potato Growers' Exchange:

Work on the Michigan Potato Growers' Exchange has been devoted principally to the standardization of the output and very considerable progress has been made during the last fiscal year. A potato specialist, Mr. Wade Weston, has been placed in charge of the work in general, under the Farm Crops Department, and an Experiment Farm, donated by the growers, has been accepted by the College. This latter development, as a result of the efforts of the Michigan Potato Growers' Exchange, demonstrates the theory that organizations should not be aimed primarily at marketing but simply using marketing as a basis of common interest, around which the organization can be built for the advancement of the industry as a whole from the point of efficiency as the ultimate object.

Co-operative marketing units of the Potato Growers' Exchange have been assisted in re-organizing and in financial problems.

The Elevator Exchange:

The Michigan Elevator Exchange has made splendid progress during the year past and is now in excellent financial condition, handling a large volume of business, and is without question the largest factor in grain handling of the State. The organization handled approximately 22% of the bean crop of the past season and a program to increase the membership is expected to still further advance the influence of the Exchange on the bean market.

Assistance has also been given to a number of local co-operative elevators in re-organizing and in financial problems.

The Michigan State Farm Bureau:

At the last annual meeting of the Michigan State Farm Bureau a plan for consolidating and co-ordinating the commodity exchanges of the State with the Farm Bureau was completed. This movement assures the harmonious development of the forces within the State and is aimed at a complete mobilization of the economic power of farming and should bring the power of the organizations of the State to bear on the larger problems effecting the agricultural interests.

The Farm Bureau Wool Department has been re-organized on a basis of complete Farm Bureau control and promises the successful handling of the pool this year. The Seed Department, without question, furnishes the best co-operative seed service of any organization of its kind in the country. The Purchasing Department of the Farm Bureau has made steady progress during the year and its plans for the future give excellent promise. The Markets Department has been consulted and has assisted in the improvement of these services.

A program, which is directly associated with the marketing work over the State, is the re-organization of the County Farm Bureaus on an economic basis, rather than a basis of political sub-divisions. The Michigan State Farm Bureau will issue a bulletin in the near future on this project. The Markets Department has given assistance to the study of this problem.

Milk and Dairy Products:

One or two large co-operative distributing plants are being organized within the State and these have received the attention of this department during the year. Work is also contemplated on the federation of the 150 creameries, which are now operating within the State, into a central marketing organization. Some preliminary work has been done on this project. A federation of co-operative cheese factories, particularly of the northern peninsula, is also receiving consideration. Work with the cheese factories will consist of assistance in the establishment of cold storage and curing facilities, with a possible amalgamation with the cheese federation in Wisconsin.

Miscellaneous:

Assistance has been given to a large number of local organizations by members of the staff in financial and re-organization problems. Work of a purely educational and promotional character has been carried on in the State by addressing numerous meetings of farmers, including annual meetings of co-operative associations, conventions and picnics.

Staff:

The staff for market organization work will consist of the following:

Leader, Hale Tennant.
Assistant Leader, Williard Cribbs.
Assistant Leader, Gifford Patch, Jr.
Assistant Leader, John T. Horner.

REPORT OF EXTENSION WORK WITH POTATOES AND VEGETABLES.

H. C. MOORE.

Potatoes: Results of work completed during the year.

Forty demonstrations were conducted in co-operation with the County Agricultural Agents. These demonstrations showed the value of seed selection, spraying, seed treatment and the use of commercial fertilizers in bettering the quality of the potatoes and increasing the yields.

One thousand twenty acres of potatoes were inspected for certification; 654 acres passed the inspections and were certified. Approximately 81,400 bushels of certified seed potatoes were sold at a premium of approximately 75 cents a bushel over U. S. No. 1 table stock. The inspection and certification work has benefited the potato industry of the State by making available for Michigan growers seed stock of good yielding strains, free from varietal mixtures and comparatively free from disease. Furthermore, the good cultural methods followed by growers of certified seed serve as demonstrations to other growers. The inspection and certification work has stimulated an interest in seed treatment, high pressure spraying, better seed, etc.

Three thousand acres of potatoes have been listed for inspection during the season of 1922.

To compare Michigan certified seed potatoes with seed from other sources over 1,000 bushels of Michigan certified seed were placed in tests in southern Michigan, Iowa, Indiana, Illinois, Ohio and Pennsylvania. In each test the Michigan certified seed and the seed with which it was compared were grown under the same soil and cultural conditions and accurate records of the yields were secured.

The following table gives a summary of the results secured:

State.	No. of records secured.	Average increased yield per acre secured by Michigan certified seed.
Southern Michigan	11	40
Iowa	6	61 2
Indiana	21	63
Ohio	69	42.8
Illinois	61	44
Pennsylvania	65	68.5

In order to test the yielding qualities of the various lots of potatoes planted for inspection, 131 strains of Russet Rurals and Green Mountains were secured from growers who applied for the inspection work and were planted in a demonstration plot. The yields varied from 368 bushels per acre for the best strain to 108 bushels per acre for the lowest yielding strain. Work with these strains is being continued in 1922; 240 other lots of potatoes have been planted this year in a similar test.

A variety test demonstration, consisting of 29 varieties planted at the Michigan Agricultural College, showed that the Russet Rural or Late Petoskey was the best late variety and that the Irish Cobbler was the best early variety.

The following is a statistical summary of the work done between July 1, 1921 and July 1, 1922:

Total number of demonstrations	47
Farm Visits made	341
Meetings Held at Demonstrations	25
Attendance at Such Meetings	388
Lecture Meetings	60
Attendance at Lectures	3,213

Special articles have been prepared for Agricultural papers and for County Agricultural Agents.

Vegetables:

Vegetable demonstrations were conducted with cucumbers, but due to severe droughts no satisfactory results were secured.

Fertilizer demonstrations conducted in Sanilac county on canning peas showed that acid phosphate gave an increase yield of shelled peas of approximately 35 per cent over that of the check plot. Similar tests conducted in Ionia and Oceana counties showed that acid phosphate and potash gave slight increases in yields of shelled peas. Nitrogen had the effect of delaying the maturity of the peas and of increasing the vine growth.

Lime and fertilizer tests conducted on lima beans at Fremont gave no results in favor of either the lime or the fertilizer; all plots gave practically the same yields.

REPORT OF EXTENSION WORK IN POULTRY HUSBANDRY.

BY E. C. FOREMAN, C. M. FERGUSON.

The work of the Extension Specialist in Poultry Husbandry during the past year has consisted largely of demonstrations and lectures on all subjects relating to Poultry Economics. Over three thousand plans of the Michigan permanent laying house and portable brooder house have been distributed. Demonstrations have been given in culling and selective breeding, caponizing, in addition to lectures on the latest and approved methods of feeding for growth and production, and brooding of chicks.

The active co-operation of the County Agricultural Agents and State Poultry organizations with the Extension Specialist greatly increased the effectiveness of this work. The large number of meetings held with a corresponding large attendance reveals the interest that has been shown in this form of agricultural specialization. Practically every county in the Lower Peninsula was visited at least once during the year.

E. C. Foreman had charge of the work for the first half of the year from July first to January first. Mr. C. M. Ferguson was appointed Extension Specialist January first and conducted the Extension work from January first to July first.

Counties visited	103
Farms visited	634
Meetings held at demonstrations	372
Attendance at meetings	10229
Lecture meetings	81
Attendance at lectures	7774

REPORT OF EXTENSION WORK ON MUCK SOILS.

BY DR. P. M. HARMER.

Outline of Work

On September 1, 1921, the writer assumed the position of Assistant Professor, Research Associate and Extension Specialist in muck soils at Michigan Agricultural College. One-fourth time is assigned to extension work, one-half to research and one-fourth to the teaching of a course in muck soils.

The extension work laid out in 1921 by Mr. Ezra Levin, formerly in charge, was in so far as possible completed and a number of changes introduced in 1922. The extension work as now conducted falls into five separate phases.

1. *Work with the county agents and farmers.* Whenever county agents or farmers are confronted with problems in the farming of muck and ask for assistance, it is given either by letter or, if necessary, by a personal visit to the area.

2. *Field demonstrations and field meetings.* The field demonstrations generally located through the county agent are a means of carrying to the community information on cultivation, cropping and fertilization of muck soils. Wherever satisfactory results are secured a field meeting of the neighboring farmers is held sometime during the summer.

3. *Winter Meetings.* Whenever it is considered advisable or requested either by county agent or farmers, winter meetings of the muck farmers are held in different localities, at which places the results of the previous years work are discussed and plans made for the coming year.

4. *Michigan Muck Farmers' Association.* This association, with a membership of approximately 1800, holds one or two meetings each year. The writer is secretary of the association. The winter meeting held at East Lansing, January 31 and February 1, 1922, had an attendance of 85.

5. *Muck Farmers' News Letter.* At intervals during the year mimeographed letters on timely subjects pertaining to muck farming are sent to all muck farmers on our mailing list. At present this numbers around 1800.

DEVELOPMENT OF MUCK FARMING IN MICHIGAN.

The total area of the muck and peat soils of Michigan is estimated at between 3,000,000 and 4,000,000 acres. The value of this land varies from practically nothing up to $1800 per acre, the variation being due to the extent of reclamation, coupled with a highly developed intensive system of truck farming on the muck in certain sections of the State. A majority of owners of uncultivated mucks are ignorant of the possibilities of the muck for crop production. Of the total area of organic soils in the State probably not more than from three to five per cent have been reclaimed by even slight drainage. Little has been done in the development of the soil on a large proportion of these reclaimed areas. Considerable is being used for wild hay or pasture, but, generally with both, yield is low and quality poor. Many times these idle muck areas are surrounded by fertile upland soil, often lying adjacent to the farmstead, and in that way lowering the value and injuring the appearance of the farm. Where a high development of muck farming has been reached, very good returns are secured, values of $800 to $1000 per acre from such crops as celery and onions not being uncommon.

It is quite generally admitted that a higher percentage of failures occurs in the farming of Michigan muck and peat lands than is true in the farming of any other type of soil. This is due to the fact that the problems confronting the muck farmer are decidedly different and harder to overcome than those met with on mineral soil. Sufficient drainage, without excessive drainage, must be secured, and proper cultural methods must be adopted before crops can be produced. Danger of summer frosts and winter killing, the chemical composition of the muck, high or low lime, the market demand must be considered in the selection of crops to be grown. As the natural fertility of organic soils generally is depleted after a very few crops have been grown, fertilization of the muck soon becomes an important factor in crop production.

The area of muck in the State now used for the production of celery has been placed at 3500 acres, of which 3000 acres is used for commercial growing. A considerable area also is used for the growing of mint. Both these crops have a limited market demand. At the present time there is a considerable over-production of mint oil, resulting in a marked decrease in price. Until further work has been done on the storage of celery for winter and spring market, any large increase in celery acreage would likewise result in rendering celery growing unprofitable. Because of this fact, the tendency of the extension work with muck soils is to direct the prospective muck farmer toward a system of diversified farming, with a selection of crops which are in general demand, adapted to muck soils and which at the same time are able to withstand, without injury, a considerable amount of frost.

THE FIELD DEMONSTRATION

1. *General Crops.* For the purpose of demonstrating to the farmer, whose farm contains a muck area, the crops for which his muck is suited and to show him the need of proper fertilization for the production of good yields, co-operative experimental projects have been established on various muck areas scattered over the State. Various crops suited to muck soil are treated with a number of fertilizers, applied alone and in combination on the different plots. This method is essential because different muck deposits vary considerably in fertilizer requirements. Results from two of the crops grown on one of these projects in 1921 are given in Table 1. Thirteen of these projects with general farm crops have been located for the season of 1922. These are locatd on the farms of Clifford Morse, Allegan Co., E. W. Kingery, Berrien Co., J. H. Cornell, Clinton Co., H. Thorpe, Eaton Co., Jotham Allen, Gratiot Co., M. A. Wright, Huron Co., A. L. Johnson, Leslie and W. A. Thomas, Lansing, Ingham Co., Thomas Graham, Lapeer Co., H. I. Sippy, Oceana Co., J. D. Goldberg, Ottawa Co., Charles Wadsworth, St. Joseph Co. and E. V. Root, Van Buren Co. The area of each of these projects varies from one to two acres in extent. A copy of the fertilizer treatments is given in Table 2.

2. *Celery.* While celery has been grown on a commercial scale on Michigan mucks for over forty years, little commercial fertilizer has been used on that and other truck crops until comparatively recently. Truck farmers have been largely dependent on manure shipped in from the cities, principally Chicago. With decrease in supply of manure and increase in freight rates, the cost of fertilizing muck with manure has made the practice very expensive. In turning to commercial fertilizers, truck growers have been largely without information as to the kind of fertilizer or fertilizers to apply or the rate of application to make. To obtain information as to the fertilizers needed, co-operative experiments were conducted with several celery growers during the past year. The results obtained from one of them are presented in Table 3.

TABLE NO. 1—GENERAL CROPS ON MUCK SOIL—GRAHAM FARM—LUM, MICHIGAN.

Fertilizer treatment.	Yield per acre.	Gross value per acre.	Cost of fertilizer per acre.	Net return per acre.	Increase or decrease over unfertilized muck with cost of fertilizer deducted.
Potatoes (1).					
N	66.1	$49 57	$3 60	$45 97	$8 92
P	59.2	44 40	3 00	41 40	4 35
K	147.7	110 77	7 00	103 70	66 65
O	49.4	37 05	....	37 05	....
NP	55.9	41 92	6 60	35 32	1 73
NK	110.0	82 50	10 60	71 90	34 85
PK	126.0	94 50	10 00	84 50	47 45
NPK	133.2	99 90	13 60	86 30	49 25
Manure	103.8	77 85	24.00	53 85	16 80
Sugar Beets (3).					
N	2.5	$15 00	$3 60	$11 40	$2 40
P	2.1	12 60	3 00	9 60	4 20
K	8.2	49 20	7 00	42 20	28 40
O	2.3	13 80	....	13 80	....
NP	3.0	18 00	6 60	11 40	2 40
NK	11.1	66 60	10 60	56 00	42 20
PK	9.4	56 40	10 00	46 40	32 60
NPK	10.8	64 80	13 60	51 20	37 40
Manure	10.3	61 80	24 00	37 80	24 00

(1) Calculated at 75 cents per bushel.
(2) Manure valued at $2.00 per ton.
(3) Calculated at $6.00 per ton.

TABLE NO. 2.—FERTILIZER TREATMENTS FOR MUCK PROJECTS SUPPORTING GENERAL FARM CROPS, 1922.

Plot No.	Fertilizer application pounds per acre.		
	Acid phosphate, 16 per cent.	Muriate of potash, 50 per cent.	Nitrate of soda, 15 per cent.
1	Check		
2	0	300	0
3	100	300	0
4	200	300	0
5	300	300	0
6	300	200	0
7	300	100	0
8	300	0	0
9	Check		
10	300	300	0
11	300	300	100
12	Manure, 12 loads	0	0
13	Manure, 6 loads	100	0
14	Check		

TABLE 3—CELERY ON MUCK—HUDSONVILLE—1921.

Fertilizer treatment.	Yields per acre.		Total returns per acre.	Cost of fertilizer per acre.	Net returns per acre.	Increase or decrease over unfertilized muck with cost of fertilizer deducted.
	Trimmed celery, lbs.	Cases.				
O	10,500	500	$400 00		$400 00	
N	10,000	475	380 00	$10 80	369 20	30 80
P	11,400	550	440 00	6 00	434 00	34 00
K	12,600	600	480 00	24 50	455 50	55 50
O	10,500	500	400 00		400 00	
NP	11,400	550	440 00	16 80	423 20	23 20
NK	12,800	600	480 00	35 30	444 70	44 70
PK	17,000	800	640 00	30 50	609 50	209 50
NPK	18,000	850	680 00	41 30	638 70	238 70
O	10,500	500	400 00		400 00	
Average check plots	10,500	500	$400 00		$400 00	

(1) Returns from celery calculated at 80 cents per case.
N—Nitrate of soda.
P—Acid phosphate.
K—Muriate of potash.
O—No fertilizer.

During the season of 1922, co-operative demonstrations are being conducted on the celery fields on several different muck deposits, with the idea of determining both the kinds of fertilizer needed and the rate of application of the different fertilizers which will give an optimum return on the investment. In one case a study is being made of the effect of overhead irrigation on the benefits secured by fertilization. Methods of fertilization of the crop by surface application and by application below the plant are also being compared.

The celery projects of 1922 are located on the farms of Born Bros. and C. Schneirla of Bay Co., Wm. Kooienga, Kent Co., M. A. Wright, Huron Co., J. Bloemberg, H. Kiel and H. Ringerwole of Ottawa Co. and A. E. Sutton, Washtenaw Co. On the farms of Wm. Kooienga, Kent Co. and M. A. Wright, Huron Co., onion projects have been established while on the latter farm a cabbage demonstration is also located. These are similar to the celery projects in the nature of the fertilization and each covers an area of from one-third to one-half acre. The system of plot fertilization is given in Table 4.

3. *Mint.* Owing to the low return per acre, many mint growers plan to turn to other crops. To some extent, this is being encouraged. At the same time, fertilization studies are being conducted with the idea of increasing the production of mint oil per acre at a lower cost per pound. This, it is thought, will allow a profit even at the present low prices of mint oil. Results representative of those secured from the 1921 projects are given in Table 5. Two field demonstrations are being carried on in this crop during the present season. These are located on the farms of Dr. W. P. Bope, Decatur and E. V. Root, Bangor, VanBuren Co.

4. *Pasture.* On many muck areas the presence of buried roots and logs renders breaking up very difficult. For that reason, it has been considered better policy to leave such soils as pasture. During the season of 1922, experiments are being conducted on pastures on two different deposits, for the purpose of improving both yield and quality, by combining fertilization with a seeding in of better pasture grasses. These are located on the farms of J. H. Cornell, Clinton Co., and M. A. Wright, Huron Co.

WORK AT CHANDLER'S MARSH.

Mr. Wilder Thomas kindly placed at the disposal of the writer 7 acres of muck to be used as a field demonstration. This is located on Chandler's Marsh two miles north of the Agricultural College at East Lansing. Two acres of this has been used as a fertility project with general farm crops (mentioned above). On another two acres, a fertility demonstration is being conducted with various truck crops. On two acres the co-operation of the Farm Crops Department has been secured in making a variety test of several farm crops. The Horticultural Department is co-operating in making a one acre variety test of a number of truck crops. Information regarding the varieties of different crops which are best adapted to muck soil is greatly needed. A monster field meeting is planned for this demonstration for some date during the late summer.

WORK ON SIPPY MARSH.

Besides the regular fertilizer plots on the farm of Mr. H. I. Sippy at Hart, Oceana Co., a cultural demonstration is being conducted on one acre of corn, one of rye, one of sunflowers and one of meadow. Various systems of plowing, rolling and cultivating are being compared. A variety test of corn is also being carried on.

LABORATORY STUDY.

Along with the co-operative fertilization demonstrations mentioned above, a chemical study of the muck soils is being made in the laboratory. The proportions of organic and inorganic materials and the content of lime in a muck soil are important in determining the adaptability of different crops and the probable fertilizer needs of the soil. The effects of fertilization on the sugar content of sugar beets and on the cooking qualities of potatoes grown on the muck is being studied. All mint plots are harvested and the mint distilled in the laboratory in order that the effect of fertilization on the output of mint oil may be determined.

TABLE NO. 4—FERTILIZER TREATMENTS FOR MUCK PROJECTS SUPPORTING CROPS OF CELERY, ONIONS, OR CABBAGE.

Plot No.	Fertilizer application pounds per acre.		
	Acid phosphate, 16 per cent.	Muriate of potash, 50 per cent.	Nitrate of soda, 15 per cent.
1	Check		
2	0	750	0
3	250	750	0
4	500	750	0
5	750	750	0
6	750	500	0
7	750	250	0
8	750	0	0
9	Check		
10	Manure, 20 tons		
11	750	750	100 (1)
12	750	750	300
13	750	750	0 (broadcast)
14	750	750	0 (deep furrow)
15	750	750	0 (surface row)
16	Check		

(1) 200 lbs. to be applied late in season.

TABLE NO. 5—YIELDS OF MINT AND MINT OIL. MUCK EXPERIMENTAL PLOTS—DR. BOPE—DECATUR 1921.

First Crop.

Plot No.	Treatment.	Yield per acre.			Lbs. green wt. to produce 1 lb. oil.
		Green wt. tons.	Dry wt. tons.	Oil, lbs.	
1	P	14.80		41.75	709
2	K^2SO^4	14.30		52.63	543
3	KCL	14.08		43.75	644
4	Ck	9.51		34.50	551
5	PK^2SO^4	15.06		50.63	595
6	PKC1	14.80		40.88	724

Second Crop.

Plot No.	Treatment.	Green wt. tons.	Dry wt. tons.	Oil, lbs.	Lbs. green wt. to produce 1 lb. oil.
1	P	5.78	1.02	14.62	791
2	K^2SO^4	6.60	1.43	15.62	845
3	KC1	5.62	1.01	17.52	641
4	Ck	3.60	0.77	12.69	568
5	PK^2SO^4	5.56	1.08	14.98	742
6	PKC1	5.30	1.09	15.23	696

Total Crop.

Plot No.	Treatment.	Green wt. tons.	Dry wt. tons.	Oil, lbs.	Lbs. green wt. to produce 1 lb. oil.
1	P	20.58		56.37	730
2	K^2SO^4	20.90		68.25	612
3	KC1	19.70		61.27	643
4	Ck	13.11		47.19	556
5	PK^2SO^4	20.62		65.61	629
6	PKC1	20.10		56.11	716

REPORT OF EXTENSION WORK WITH SOILS.

BY G. M. GRANTHAM.

The Extension work in Soils is divided into two distinct divisions, namely, the extension schools held during the winter months of January, February and March and the field work carried on during the remaining months of the year.

The Extension schools are usually held in co-operation with the County Agent. The problems in which the farmer is mostly interested are discussed as fully as time will warrant. At a number of meetings samples of soils and marls are brought by farmers and simple tests for acidity or lime contents are conducted, explaining where equipment for such work can be obtained, the reactions of tests and how such tests can be carried on by the farmer under field conditions. The subjects discussed are varied according to the different soil locations of the State, nature of the meeting and class of people attending the meetings. The discussion of the problems of the individual before and after such meetings can be rated as no small part of this branch of work.

Numerous evening meetings are held during the summer months, where discussions similar to the above are emphasized.

The summer field work is divided into two divisions, namely, the carrying on of accurately controlled demonstration plots and the field meetings held on such demonstration fields. The demonstration plots consists of work along the following lines: The use of commercial fertilizers of different kinds and amounts on various soil types, rate of application of manure and effect of re-inforcing of manures with phosphate, different kinds and applications of limes and marls, the effect of fineness of division of ground limestone as covering a rotation; the use of various crops as green manure crops and their period of duration in the soil, and the effect of tillage operations on control of moisture and crop growth. Accurate records are kept of these projects not only for one year but for a number of years. Yield records are also kept, the yields being taken by the field man rather than by the farmer or the person with whom we are co-operating.

The field meetings are usually held on the demonstration plots during the growing season. On the field containing a small number of plots usually a short meeting is held but where a larger number of plots are located a half day meeting is arranged.

In the field work phase of extension work results are derived from year to year but we do not feel the work has been completed, for as the demonstration covers a number of years it is of more value than a one year demonstration. On the Cass County Field, where our largest demonstrations are located, our first year's results were scarcely striking enough to bring before the farmer while at the close of the four year rotation a lime and fertilizer treated plot had yielded approximately $75 more of produce than an adjacent untreated plot. This same fact holds true on a number of demonstration fields. Thus we feel it unjust to quote results as completed work.

New work on different soil types and lime fertilizer treatment on the catch and growth of alfalfa and clovers, as well as fertilizer demonstrations on corn, has been the principal new work undertaken in the last year.

STATISTICAL SUMMARY.

Total number of demonstration fields	52
Total attendance at meetings and field days	3582

Fairs Attended:

Western Michigan State Fair, Grand Rapids, Michigan.
Eastern Michigan State Fair, Detroit, Michigan.

Exhibit material was furnished a number of county agents for exhibits at County Fairs.

BULLETINS

OF THE

Agricultural College Experiment Station

ISSUED DURING THE

YEAR ENDING JUNE 30, 1922

DISEASES OF BEES IN MICHIGAN.

Special Bulletin No. 107.

BY RUSSELL H. KELTY.

Introduction.

Foul-brood is the name given to certain diseases which attack bees in the brood stage. Since it causes a yearly loss of many thousand colonies and the destruction of a great amount of apparatus, beekeepers consider foul-brood to be a very serious menace to the industry of honey production. Each succeeding year greater effort is made to control its spread, through education and legislation; and armed with the more perfect knowledge which thorough investigation has developed, the beekeeper is now better able to cope with the situation than heretofore.

The beekeeping profession owes much to Dr. G. F. White, whose thorough and exhaustive research work on bee diseases has given to the world a great deal of information concerning the foul-broods, and who from his work, has been able to offer invaluable suggestions as to methods of treatment.

Foul-brood is found practically wherever bees are kept both in America and in foreign countries. Certain areas in the United States are now disease free, however, probably because no infecting material has yet been introduced. The ease and rapidity with which foul-brood spreads from place to place is well-nigh disheartening, and it is only by constant vigilance and rigid adherence to precautionary measures that the fight against its ravages can be won. Under existing conditions of legislation and beekeeping practice it is folly to expect to continually remain free from disease. Each beekeeper must be forever watching for its appearance and prevent its spread by immediate and effectual treatment. It is for the purpose of supplying the beekeeper with the knowledge necessary for the control of foul-brood that this bulletin is written.

American Foul-Brood.

Of the three foul-brood diseases, American foul-brood is considered the worst. The disease is called American not because it is found more generally in America than elsewhere, but because an American scientist, Dr. G. F. White, Bureau of Entomology, Washington, D. C., was the first man to isolate the causal organism.

Due to the fact that colonies affected with American foul-brood must be deprived of their stores and combs and placed in a clean hive, a considerable loss is experienced by the beekeeper. The disease is infectious in nature and easily carried from hive to hive through the medium of honey. Whole yards may become diseased during a comparatively short period if not given close attention. Also as the method of treatment of American foul-brood is altogether different from the usual treatment of other foul-broods, it is essential that the beekeeper be familiar with the symptoms of the disease so that he may recognize it immediately and be able to distinguish it from other diseases.

CAUSE.

The cause of American foul-brood is a bacillus called **Bacillus larvae** (White). This bacillus is very minute in size. It would take nearly 10,000 of the organisms placed end to end to cover an inch. The organism can be easily detected in dying or decayed larvae and scales by the use of the microscope, and in cases in which beekeepers are doubtful as to the correct diagnosis, a sample of the diseased material should always be submitted to a laboratory, where examination with a microscope can be made. Samples in which scales are predominant, and which lack the usual characteristic symptoms of either of the foul-broods, should always be examined with the microscope. One of the peculiar facts concerning American foul-brood is that when sample is examined microscopically it usually contains but one kind of bacteria, **Bacillus larvae,** whereas samples of European foul-brood may contain any one or all of several different bacteria.

American foul-brood invades the colony by attacking the young larvae during the time when they are being fed by the nurse bees. These infected larvae usually die just after the cells are capped, although larvae may be found dead of American foul-brood in rare cases still curled up in the end of the cells; on the other hand American foul-brood may kill larvae well advanced in the pupa stage. Adult bees are not affected.

Larvae of all three classes, i. e., worker, drone, and queen, may become infected, although the worker larvae are found diseased most frequently. In fact queen and drone larvae are seldom attacked. The experience of beekeepers has shown that no race of bees is particularly immune to the ravages of American foul-brood.

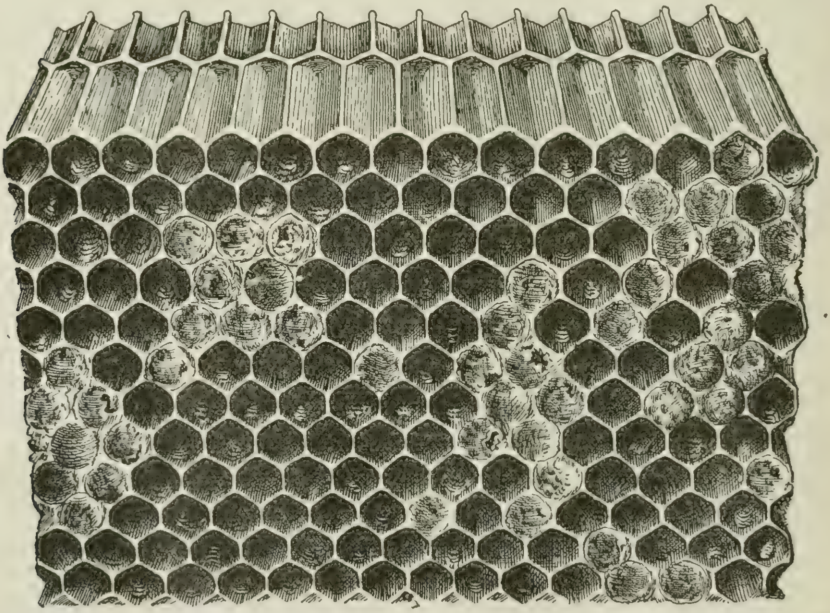

Fig. 1. American foul-brood comb, showing irregular patches of sunken cappings and scales. The position of the comb indicates the best way to view the scales. From Farmers' Bulletin 442, U. S. Department of Agr., Bureau of Entomology.

SYMPTOMS.

Since the larvae affected with the disease usually die after the cells are capped, American foul-brood is frequently well established in the apiary before the beekeeper recognizes it. The first indication of a disorder in the brood-nest is usually that of punctured and sunken cappings and a darkened color of the diseased cells. In well advanced cases the "glue pot" odor is frequently so pronounced that it can be easily recognized. Since the affected larvae die at a time when they are beginning to transform into pupae they are found lying lengthwise on the floor of the cell with the back down. Healthy larvae at this stage are white or slightly bluish in color,—appear to glisten, and the skins are quite tough. Diseased larvae first change color from the bluish-white of the healthy larvae to a light brown color. The skin also becomes tender and is easily broken. As decay goes on, the color changes to a more distinct brown, finally assuming a coffee color or chocolate-brown shade. As the change in color of the larvae progresses the skin of the larvae becomes more easily broken and the decaying material gradually assumes a stickiness or ropiness which is one of the chief characteristics of American foul-brood. The matter does not become distinctly ropy until several weeks after the death of the larvae, but when decay has progressed to the point where the remains commence to dry down into a thin "scale" this ropiness is very characteristic. When a match or toothpick is applied to the remains at this time it can be drawn out into threads from one to six inches long. This cannot be done with the remains of larvae attacked by European foul-brood, and is a distinguishing characteristic. As the decay of the larvae progresses, another symptom to be noted is the presence of a strong odor which has been frequently described as the odor of the glue-pot. This is so pronounced that in advanced cases it can be detected when the hive is first opened. Pupae dead of the disease, frequently have the tongue sticking to the top of the cell. This is rarely if ever found in cases of European foul-brood.

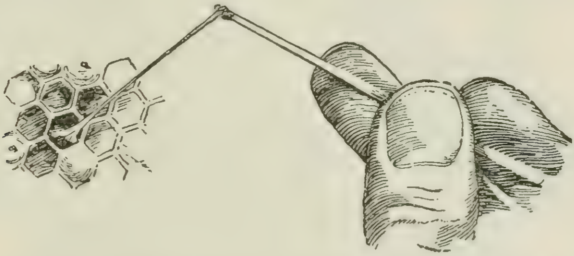

Fig. 2. The ropiness of American foul-brood. From Farmers' Bulletin 442, U. S. Department of Agr., Bureau of Entomology.

There are, then, three chief distinguishing features of larvae affected with American foul-brood, namely, coffee color, ropiness, and the glue-pot odor of the diseased material.

After the decayed material has dried down on the bottom of the cell into a thin layer known as the scale, it is not easily moved from the cell. However, there are occasional exceptions which may mislead the beekeeper. One sample of foul-brood which microscopical diagnosis proved to be American contained scales which were so loose that they were shaken from the comb. Another irregularity sometimes noted is that larvae are affected by

American foul-brood while still curled up in the bottom of the cell. Combs containing larvae which had died curled up in the bottom of the cell, but which had the coffee color, ropiness and glue-pot odor of American foul-brood have proved upon microscopical examination to be American foul-brood.

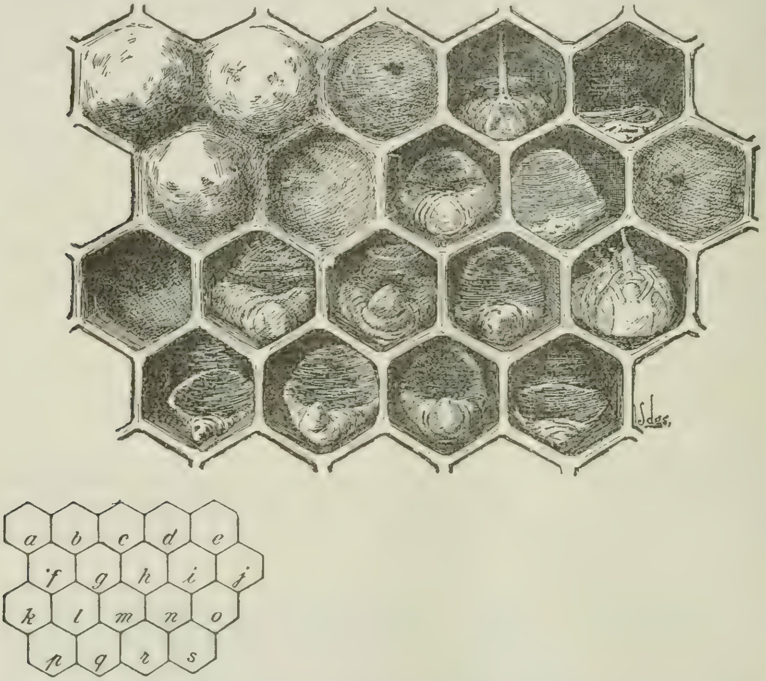

Fig. 3. Americal foul-brood; a, b, f, normal sealed cells; c, j, sunken cappings, showing perforations; g, sunken cappings not perforated; h, l, m, n, g, r, larvae affected by disease; e, i, p, s, scales formed from dried-down larvae; d, o, pupae affected by disease. Three times natural size. From Farmers' Bulletin 442, U. S. Dept. of Agr., Bureau of Entomology.

No doubt the gross examination of larvae dead in this unusual stage of American foul-brood has led to an incorrect diagnosis of European foul-brood in some cases, and has possibly added to the confusion which has existed between the two diseases.

The scales of American foul-brood are usually uniform in thickness on the bottom of their cells, and as they are removed by the bees with great difficulty, it is very seldom that combs containing scales of American foul-brood are cleaned by bees. In all cases which have been brought to the attention of this office where bees have cleaned combs containing scales of American foul-brood, the disease has returned later.

METHODS OF SPREAD OF THE DISEASE.

The ordinary medium through which American foul-brood is spread is contaminated honey. **Bacillus larvae,** the causal organism of the disease, produces spores which are very resistant to all of the common means of control of bacterial diseases, and these spores will live in honey and diseased combs for a period of years. The robbing of diseased colonies by healthy colonies or of empty hives that have contained diseased colonies is the method by which most American foul-brood is spread. The feeding of honey from diseased colonies which are thought to be healthy, the practice known as "Equalization of Brood," the dividing of brood among weak colonies after shook swarming and other such practices, are often the means of scattering disease throughout the apiary. Frequently in such cases the disease has only begun to appear in one or two cells in the brood nest or else is present in the shape of diseased honey previously robbed from some other diseased colony and not yet actually fed to larvae to produce disease. In many of these cases the beekeeper is not aware that he has spread disease through his colonies until a few weeks later when he discovers the symptoms in the various colonies manipulated. The use of secondhand cans is another questionable practice. Frequently the honey which was shipped in the can contained disease, and the rinsing of the cans previous to use usually exposes a dilution of honey and spores to the bees. Disease is also transmitted from one colony to another by the beekeepers' hands and hive tool. However, this means of spread is not so much to be feared as the others mentioned. Bee-trees in the woods should be promptly attended to by the owner as the occupants of the tree frequently become infected with foul-brood, are killed out during the winter and then remain a source of infection for all bees within flying distance. No doubt this source of infection explains many of the non-traceable causes of infection which beekeepers meet with. The interchanging of supers, combs and other apparatus frequently practiced in extracted honey production is a prolific method of spreading foul-brood and should be carefully guarded against. Each hive, together with all combs, supers and super-covers, should be numbered, thus insuring the use of the same apparatus on the same hive every time. Leaky shipments of honey passing through the country are another means of spreading disease. Frequently apiaries are located within flying distance of railroad switches and leaky shipments of honey are robbed. The indiscriminate shipping of bees from one state to another or from one section of the state to another without the consent and inspection of a bee inspector is to be guarded against. It is probable that in this way the disease has spread so rapidly over practically the entire United States.

TREATMENT.

Bacillus larvae is very resistant to heat, drying, sunlight, chemicals and disinfectants. It has been known to live in the scales of a diseased comb for 9 years. It is this resistance to the ordinary means of control of bacterial diseases that makes the treatment of American foul-brood difficult. The treatment for American foul-brood known as the McEvoy or Shaking treatment consists of the replacing of the diseased hive, combs and honey with a clean hive and full sheets of foundation, thus forcing the bees to build new clean combs. This treatment should be given during the honey flow to prevent robbing or else performed under a tent of wire cloth or mosquito netting. When a number of colonies are to be treated, beekeepers prefer to perform the operation during the middle of the day when the majority of the bees are in the field. When only a few colonies have to be treated, the treatment should be given in the evening. If a large number of colonies are to be treated all should be shaken at the same time. Otherwise the danger of robbing is increased. Before treating the colony all equipment needed for the operation should be in readiness. A queen guard, lighted smoker, hive tool, complete clean hive with full sheets of foundation, a tightly closed hive body in which to put the diseased combs and a bee brush of some sort will be needed.

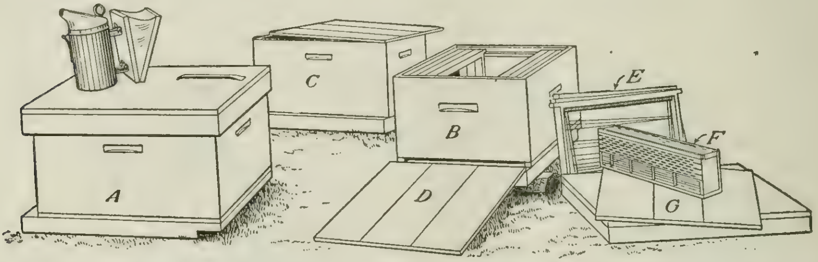

Fig. 4. Apparatus for shaking treatment: A, hive containing diseased colony (formerly in position of B); B, clean hive; C, empty hives to receive combs after shaking; D, hive cover used as runway; E, frames removed from B to give room for shaking; F, queen and drone trap; G, cover for clean hive B. From Farmers' Bulletin 442, U. S. Dept. of Agr., Bureau of Entomology.

The diseased colony is lifted to one side, within working distance of the clean hive placed on the old stand. Three or four frames are then removed from the center of the clean hive. The diseased combs with bees are removed from the diseased colony one at a time and the bees are lightly brushed into the middle of the clean hive. The diseased combs are then placed in the tightly closed hive body. This operation is repeated until all of the bees have been removed from the diseased combs. The remaining bees in the diseased hive may be shaken into the clean hive. Use every precaution to prevent spilling of diseased honey, and burn the brush used. A queen guard is then placed over the entrance to prevent the colony from absconding. The whole operation should be performed as quickly as possible to lessen the possibility of robbing. Experienced beekeepers who treat several diseased colonies at the same time prefer to save the healthy brood remaining after the treatment. This is done by piling the hive bodies containing brood from several diseased colonies over a queen excluder on a weak diseased colony whose entrance is contracted to prevent the possibility of robbing. About two weeks later this colony is also treated. Commercial beekeepers find it very convenient to use a hospital yard for diseased colonies to which all colonies are removed immediately upon finding signs of disease.

If the beekeeper has no wax-press or means of removing the wax from the diseased combs, these combs and frames should be placed in a hole in the ground and burned and the ashes buried. If the combs are to be rendered, extreme precaution must be taken to place the diseased combs in some container which is absolutely bee tight and which is stored in a building to which bees do not have access. Otherwise the treatment of diseased colonies is time, labor and equipment wasted. Comb foundation made from wax rendered from diseased combs does not transmit disease.

A diseased hive body may be cleaned by first scraping with a hive tool the inside of the walls, the grooves containing the rabbets and all parts covered with propolis. The inside of the hive body should be then scorched to a light brown with a blow-torch or flame of any sort. Frames which have contained diseased combs may be saved by first carefully removing all possible wax and propolis with a hive tool and later boiling in lye water made of one pint of concentrated lye to a boiler full of water. One boiler full of lye water will not treat satisfactorily more than two hundred frames. The lye water should first be brought to a boiling point. Then with the fire remaining under the boiler to keep up the temperature, eight to ten frames are placed in the boiler at a time, submerged and allowed to remain in the water from two to five minutes until all of the propolis and wax have been dissolved from the frames. They are then removed and placed in empty hive-bodies to dry. By this method frames can be cleaned very quickly and thoroughly at a real saving for the beekeeper.

If there is much diseased honey on the colony it can be saved by extracting. As it is very difficult to prevent robbing of this diseased honey either during the extracting or before or after, the greatest of care must be taken at all times to keep the honey in bee-tight containers in a bee-tight building. Diseased honey is suitable for eating purposes but cannot be fed to bees until after being diluted one-half and boiled in a closed vessel for twenty minutes. As the boiling caramelizes some of the sugar, boiled honey cannot be fed to bees for winter food. It is unlawful to sell diseased honey except in closed containers for commercial purposes.

There are modifications of the treatment given above but they are not recommended for beginners. Experienced beekeepers who are familiar with the principle involved use them successfully. Colonies found to be diseased so late in the fall that it is impossible for the bees to build up for winter may be shaken on solid combs of honey in which there are no empty cells for storage of diseased honey. Only strong colonies should be so handled. Weak colonies should be destroyed or united. Diseased colonies should be wintered in the cellar if possible to remove the possibility of robbing by any healthy colony in early spring or in warm days during the winter.

DRUGS.

The use of drugs in the treatment of American foul-brood or of the other foul-broods is a waste of time and material. It is extremely doubtful whether disease can be successfully eradicated by the use of any known drug, and it is certain that commercial beekeepers do not have sufficient time to spare to follow the course of procedure necessary if drugs are to be used.

European Foul Brood.

European foul-brood is an infectious disease which attacks developing bees only. The term European is given this disorder to distinguish it from American foul-brood for the reason that European investigators were the first to perform laboratory studies of the disease. This disease is found practically all over the United States except in certain areas where, propably due to the lack of introduction of diseased material, no disease is found at present. European foul-brood is not as serious in its nature as American, and is considered by the best authorities to be of little danger to the beekeeper who keeps his colonies strong and requeens annually, using stock which has proved resistant to disease. Like American foul-brood the disease is infectious, and can be easily transmitted from diseased to healthy colonies. European foul-brood spreads through the apiary and through the brood-nest of the colony at a much faster rate than American, with the result that the colony infected can become practically rotten with disease before the beekeeper is aware of it.

CAUSE.

The cause of European foul-brood has been practically determined to be **Bacillus pluton** (White). Although this organism refuses to grow on artificial media, by process of elimination it has been proved that the other organisms found in larvae infected with European foul-brood are not the exciting cause of the disease. It therefore appears that **Bacillus pluton** is the exciting cause. **Bacillus pluton** is smaller than the causal organism of American foul-brood and has a different shape. This difference in size and shape aids the bacteriologist in determining microscopically the kind of foul-brood being examined. There are present in diseased larvae any one or all of several bacteria other than **Bacillus pluton.** This fact has caused some confusion among investigators.

European foul-brood attacks the larvae at a much earlier age than does American, usually at two days of age or older. As the period of sickness has been determined to be two days or more, larvae are at least four days old when they die. In fact it is at this age that larvae are most often found dead of European. However, as larvae dead of the disease are sometimes found in capped cells it is evident that older larvae are also occasionally attacked. All three classes of larvae are infected, and unlike American, European foul-brood frequently attacks drone and queen larvae.

Experience has proved that black bees are more susceptible to the disease than are Italian. Furthermore it is possible to develop strains of Italian bees by selection which are more nearly immune to the disease than others. For that reason beekeepers in European foul-brood districts should endeavor to raise their own queens from colonies which show resistance. The disease is most prevalent in the spring time. The coming of the honey flow will often remove all traces of the disease in the colony, while cessation or lack of a honey flow seems to assist in the destruction of the colony.

SYMPTOMS.

It has been shown that there are three stages of development at which larvae are attacked by European foul-brood. The early stage at which they are attacked is when they are at least four days old and lie in the bottom of the cell in a C shape, not entirely filling the end of the cell. It is at this stage that European usually attacks larvae. They are also attacked at a slightly later stage of development, at which time they occupy the whole of the end of the cell and have begun to stretch out into the base of the cell. Larvae are frequently found dead of European at this stage. European foul-brood also attacks larvae after they have been capped in the cell, and it is from brood found dead at this stage that much of the confusion in differential diagnosis between European and American is experienced. Healthy larvae in the various stages mentioned are perfectly white in color, sometimes with a slightly bluish tinge, plump and rigid, and appearing firm. The position occupied in the cell will depend, of course, on the stage of development. Those in the first stage are still curled up in the end of the cell, while those in the last stage will be stretched out the entire length of the cell and capped over.

When attacked by the disease the larvae turn color from a healthy white to a yellowish tinge, sometimes more distinct than at others, later turning to a brownish color as decay goes on, and finally becoming a dark brown in the final stage of decay. The brood-nest has the appearance of a pepper box,

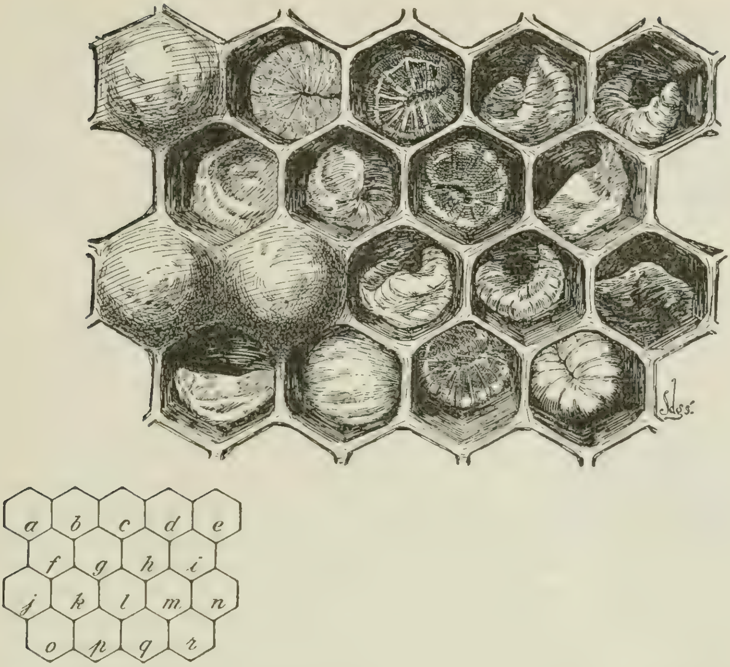

Fig. 5. European foul-brood: **a, j, k,** normal sealed cells; **b, c, d, e, g, i, l, m, n, p, q,** larvae affected by disease; **r,** normal larva at age attacked by disease; **f, h, n, o,** dried down larvae or scales. Three times natural size. From Farmers' Bulletin 442, U. S. Dept. of Agr., Bureau of Entomology.

after the disease has progressed somewhat, due to the scattered cells of disease among the cells of healthy brood. Occasionally a larvae will be found dead of the disease in capped cells, and then there will be punctured and sunken cappings present. However, the disease attacks the larvae before they are capped over as a general rule, and therefore not as many punctured and sunken cappings are found as in American foul-brood. Usually there is very little odor present. Exceptions to this rule have been reported, however, and it is probable that putrefactive organisms such as **B. alvei,** which are present in the larval remains, are the cause of these odors. The writer has examined microscopically several samples of foul-brood in which were larvae containing the causal organisms of both American and European foul-brood. Such dead larvae have unusual odors; some that of decaying meat, others, the odor of rotting vegetables. These cases, although exceptions, emphasize the advisability of microscopic examination as a check to gross diagnosis, especially of those samples which do not have all of the regular symptoms.

In the process of decay the skin of the larvae becomes tender and easily broken, much the same as in American, but at no time is there the ropiness of the decayed material that is found in American foul-brood. Just before the decayed matter dries down into the scale the material is sometimes stringy and more or less granular, but does not possess any of the elastic qualities of American foul-brood. During the first stages of decay the content of the body is watery in consistency. The tracheae of the larvae frequently stand out as white lines resembling spokes in a wheel. This characteristic may remain after the scale is formed and is one of the ways of distinguishing European foul-brood. Larvae which are older than four days commence to stretch out in the cell as room for growth is required, and when attacked at this period will be found dead in a sort of a cork screw position. Sometimes the larvae are attacked after they have stretched out in the bases of the cells, but this is not the general rule. The scales are not adhesive to the walls of the cell as are the scales of American foul-brood, and can be removed by the adult bees. Furthermore, diseased larvae which have not dried down in the scale are sometimes removed by the adult bees in piecemeal.

METHODS OF SPREAD OF THE DISEASE.

European foul-brood is spread from diseased to healthy colonies by means of the transmission of infected honey or other diseased material. The robbing of diseased colonies by healthy ones is probably the most frequent method of spread. The interchanging of combs of brood from diseased to healthy colonies also transmits the disease. It is possible that nurse bees from the diseased colony may carry the virus on their mouth parts and body, thus infecting healthy larvae in feeding them. It is also probable that occasional nurse bees from diseased colonies return to healthy colonies after play flights, carrying diseased material. This has not been definitely proved. As the virus lives in honey about 7 months there is slight danger of infection from feeding honey which has been carried over winter. Dry extracting combs which have contained honey from a European foul-brood colony would probably transmit the disease to brood reared in those combs. However, as the virus lives for a shorter period of time in the scales and honey than the virus of American foul-brood, the European is more easily controlled.

TREATMENT.

The method of treatment of European foul-brood will depend upon the progress the disease has made in the colony, the race of bees, the strength of the colony and the honey flow. It is known that Italian bees resist European foul-brood better than other races, probably due to their superior ability as house cleaners. It is also known that European foul-brood is a disease of weak colonies principally and will usually disappear in the colony with the arrival of a good honey flow. If the disease has not made considerable progress in the brood-nest by the time the treatment is given it is advisable to allow the bees to clean up the diseased combs. If on the other hand a very large percentage of the brood nest is diseased it is questionable whether it is best to force the bees to clean up the diseased combs or whether the colony should be shaken on to full sheets of foundation and given a young laying queen of resistant Italian stock. If the bees are to be forced to clean up the disease the following method is followed: First, make sure that you will have a young laying Italian queen available two weeks from the time the treatment is given. Kill the queen in the diseased colony, and if the diseased colony is weak in bees double enough diseased colonies together to make strong colonies. Allow these colonies to remain queenless for from ten days to two weeks, then introduce the young laying queen of resistant Italian stock. If the attack is mild and the colonies are already of pure Italian stock it may be desirable to cage the queen for ten days instead of killing her. Dr. Miller used this method successfully. If the queen is old, and especially if she is not Italian, it is always best to kill her. The period of time that the colony remains queenless will depend upon the length of time necessary for the bees to make the combs free from scales. However, it is not necessary to wait until the diseased combs are completely clean as the introduction of a young laying queen sometimes stimulates the bees to greater activity in cleaning house, and although a few cells of disease may appear after the queen has been introduced it will soon disappear completely.

It is extremely desirable to treat at the beginning of or during a honey flow, as the incoming nectar and the hive activity associated with a honey flow stimulates the young bees to greater activity in the removal of diseased material and greatly assists in the success of the treatment. It is very necessary to have the colonies as strong as possible during the queenless period and full of young bees. It is not considered necessary to disinfect hives which have contained European foul-brood before using for healthy colonies. Combs which are so foul that it is not advisable to compel bees to clean them should be treated as American foul-brood combs.

SAC-BROOD.

Sac-brood is an infectious disease of bees in the brood stage, the cause of which has been proved to be a filterable virus. Its effect upon the colony is usually not serious. Due to the fact that larvae die of sac-brood at approximately the same time as those attacked by American foul-brood a careless observer might, at first glance, mistake sac-brood for American. However, the position of the scale in the cell, well compared to the shape of a Chinaman's shoe, together with the looseness of the scale in the cell makes differentiation simple.

The method of spread of the virus is not well known, nor is the relation of the race of bees to resistance to the disease of value. In ordinary beekeeping practice, a treatment for sac-brood is rarely necessary. Requeening a colony which has a severe attack, with a vigorous young laying queen usually cleans up the disease. The virus is not present in the scales, and a hive which has contained a colony suffering from sac-brood should be all right for use with a healthy colony without treatment.

NOSEMA DISEASE.

Nosema disease is a disease of adult bees caused by the protozoan **Nosema apis.** It is probable that the disorder caused by **Nosema apis** is recognized by other names in different countries and in different sections of the United States. It is not known that there is any relation between Nosema disease and Isle of Wight disease, and there probably is not. The disease attacks the adult bees through the alimentary tract. Usually the first symptoms of nosema disease is weakness of the colony. As the affected bees behave similar to healthy ones, a slight attack on the colony would never be noticed. The disease does not affect the brood, and work in the colony goes on naturally. The method of spread of the disease is not well known. The spores of the disease pass out of the affected bee in the excrement. Should this excrement fall in the water supply of the bees it would furnish one means of spread. The bodies of bees dead from nosema disease in the water supply would probably transmit the disease. The infection may or may not kill the colony. It does, however, weaken the colony to such an extent that in many cases little or no surplus honey is stored. As diseased colonies become weak it is probable that robbing is one means of spread of the disease. The disease is not considered of great importance in Michigan at present.

Dysentery.

Dysentery is not a disease, but is the result of prolonged retention of the feces by the bees during the winter months. This results in the production of an irritation in the intestines of the adult bee with the result that the feces which can no longer be held are voided within the hive. Evidence of dysentery is found in the spotting of the frames and interior of the hive and entrance. Colonies suffering from dysentery usually begin brood-rearing earlier than normal in the spring, and as a result lessen instead of improve the chance of recovery. Dysentery is very likely to produce the disorder referred to as spring dwindling.

Spring Dwindling.

Spring Dwindling has doubtless been used to indicate various disorders. The term as it is commonly used by beekeepers refers to the condition of a colony in the spring in which the number of bees very rapidly diminishes. This is usually the result of the death of those bees which have worn themselves out in the process of maintaining the cluster temperature during the winter. Colonies without sufficient packing during the winter, and especially colonies composed of a majority of old bees the fall before, are especially likely to appear in this condition. This disorder is not a disease but a condition of the colony which can largely be prevented by the beekeepers who take proper precautions in the preparation of the colony for winter.

Paralysis.

The disorder referred to by beekeepers as paralysis or Disappearing Disease or Palsy is little understood. The disease may suddenly attack every colony in an apiary. Affected bees will be observed on the grass in front of the hive and throughout the apiary in distorted positions, some crawling upon a blade of grass and attempting to fly; others fanning feebly. Still others will rear themselves on their fore legs and mandibles, fanning, while others will be found crawling on the grass with abdomen pulsating rapidly, which has given rise to the term Palsy. The disease may appear throughout the apiary one day and be gone completely the next, or it may remain in the apiary several days or longer. In some apiaries a few colonies are affected throughout the season, whereas all others appear to be healthy. The disease may reappear after it has once left the apiary. The irregularity of its behavior has given rise to the term "Disappearing Disease." It is probable that more than one disorder is indicated by the term Paralysis, but actual proof of this is lacking. The cause of the disease is not known, and no known treatment is satisfactory. The most serious effect of the disease is to so weaken the colonies affected as to prevent the storing of surplus. Apparatus from colonies which have been killed by the disease can apparently be used for healthy colonies without reinfection.

Isle of Wight Disease.

Isle of Wight Disease is a disease of adult bees which causes serious losses in England and neighboring territory. Usually the symptoms are similar to those of nosema disease, although it is very likely that the two diseases are different. Recent investigators have demonstrated the possibility that the disorder is caused by a mite which occupies the tracheae or breathing tubes of the bee, thereby shutting off air circulation. The disease is not considered serious in Michigan.

NECESSARY PRECAUTIONS.

"An ounce of prevention is worth a pound of cure." The beekeeper can often save himself much trouble and expense by preventing disease from getting a foot-hold in his apiary.

Never feed honey—unless you are absolutely sure it is not infected—without diluting one-half and boiling in a closed vessel for twenty minutes.

Never purchase bees from anyone without inspection by a competent person or else with inspector's certificate attached.

Never allow a weak or dead colony to be robbed out. It may be diseased. Contract the entrance of weak colonies to one bee-way in robbing season.

If you attempt to winter diseased colonies, if at all possible winter them in the cellar where they can not be robbed out in early spring if they die in winter.

If you winter outdoors see to it that all colonies not defending their entrance in early spring are closed to prevent robbing.

The use of old combs and second hand apparatus of all kinds is dangerous.

Never expose sweets of any kind during the robbing season. If robbing is once started your bees may visit diseased colonies in the neighborhood.

Be on the watch continually for symptoms of disease in your apiary.

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THE ROBUST BEAN.

Special Bulletin No. 108.

FRANK A. SPRAGG AND E. E. DOWN.

DESCRIPTION.

The Robust is a variety of common white navy bean that has consistently outyielded all other varieties compared with it at the Michigan Agricultural College. It originated from a healthy individual plant that was selected from among a lot of commercial beans containing mosaic, in 1908.

The Robust takes more time to develop a root system, but in the end develops a larger root area than ordinary varieties. The earlier varieties are first to set bloom, while later the Robust blooms profusely and has a very much larger setting of pods. The Robust cannot be said to resist drought any more than other varieties. In case a test is planted on sandy soil and drought kills the beans in late summer, other varieties may yield more because they set their pods earlier and mature more beans before the hot spell.

On the other hand, the Robust is able to set pods in a hotter sun than can the common varieties provided the soil contains enough moisture at that time to maintain plant sap. In 1916 the Robust was the only variety that had a good setting of pods at this Experiment Station, as the other varieties dropped their flowers during a hot spell at blooming time. Most of them lost the second setting of flowers and failed completely. Plant selections were made from the Robust and from some of the better commercial varieties that summer, and planted in plant-rows during the following season (1917).

The leaves of the Robust are usually more wrinkled and drawn in at the edges than are those of other varieties, which may be quite flat. The leaves of most varieties turn yellow and drop more or less all summer, probably due to bacterial blight. The Robust holds its foliage and maintains it in a profuse development until a few days before harvest time, when the foliage turns yellow and drops off as a whole. Because of this characteristic, it will normally withstand a frost that will kill the leaves without injuring the pods. The foliage then opens up, and the pods mature rapidly. A month before harvest the Robust is normally picked out as the greenest variety in a series.

OTHER EXPERIMENT STATIONS TEST ROBUST BEANS.

Besides the tests carried on at this Experiment Station, the Robust has been tested by several other stations, notably New York, Connecticut, Rhode Island, Quebec, Minnesota, and Iowa. These stations give favorable reports, saying that the Robust variety yields more than the average variety, and in many cases considerably more. In New York, Professor Donald Reddick has tested several strains of Robust and found them to be immune to the Mosaic disease. It seems that resistance to Mosaic is very important in New York State as the bean industry was in danger of being destroyed by the disease. It is yielding fully as well for them as for us.

In Iowa the test was made in connection with a soybean variety series, a number of common beans being included. Ove Jenson, the experimenter, reported that the Robust produced four times as much as any other common variety in the season of 1917.

During the same year, G. W. Putnam obtained good results at Delevan, Kansas. In short the Robust is a high producing, disease and heat resistant variety of white navy bean that should be given a fair trial in every bean section in Michigan.

This bean, according to reports is becoming a standard in New York and some portions of the middle west.

SELECTION AND CROSSING.

Beginning in 1907, plant selections were made from new commercial varieties almost annually, until in 1917 there were 173 commercial sources of seed that had thus been included in the work. Mosaic was bad among the beans in 1908, causing a large number of plants to fail to set pods. Only productive plants were saved for future plantings. It was also clear in 1909 that many lots of beans were mixtures of early and late strains as they came to the Station.

Some crosses were obtained in 1912, which began to segregate in 1914, and out of these crosses originated a confusion of types in the years that followed up to 1918, when 200 individual plant selections from these beans were included in the plant-row series. Two graduate students wrote theses on these beans during the years 1914 to 1917.

A new lot of crosses were made by G. W. Putnam in the winter of 1916-17. These new crosses began to segregate in 1918, and have been extensively planted and selected during the years 1919-1920. Ont of this work it is expected that a white navy bean may be obtained that is immune to anthracnose as well as mosaic, but this work must continue a few more years before such a bean can come true to type and be given a yield test.

In 1918 several hundred individual plant selections were made in farmers' fields, widely scattered over Michigan. From these new accessions, about 200 plant rows were planted in 1919. The better yielding strains were increased in 1920 so as to enter a new varietal series, beginning 1921.

YIELD TESTING.

Table I shows the results of varietal testing during the years of 1912 and 1914. The Robust (No. 81302) was used as a check, being planted each fifth plant inside of edges. A plat consisted of two rows, each 637 feet long and 28 inches apart. At harvest time the puller put the two rows into one. The threshing was done carefully to prevent varieties from mixing and to obtain all the seed.

TABLE 1, BEAN VARIETAL SERIES 1912-1914
Percentage Yields of Robust (81302)

Variety.	1912.	1913.	1914.	Av. %.	Bus.* per A.
Robust	100.00	100.00	100.00	100.00	35.0 ±1.1
82103	79.44	73.50	52.13	68.36	23.9 ±1.0
Cook	64.54	71.96	63.25	66.58	23.3 ±1.0
No. 81901	75.00	67.95	54.48	65.81	23.0 ±1.0
Shoesmith	74.77	62.48	57.40	61.55	21.5 ±1.0
No. 84204	68.77	66.47	44.89	60.04	21.0 ±1.0
Landis Untreated	62.24	56.45	48.00	55.56	19.4 ±0.8
Landis Inoculated		38.03	44.88	41.45	14.5 ±1.0
Landis 1–300 Formalin		48.03	43.79	45.91	16.1 ±1.0
Landis 1–500 HgC12		65.22	46.28	55.75	19.5 ±1.0
Boston	54.54	58.13	53.12	55.26	19.3 ±0.9
Scully		47.19	46.90	47.04	16.5 ±1.0
White Kidney	42.08	57.72	37.90	45.90	16.0 ±0.7
Ogemaw Soy	51.19	39.65		45.42	15.9 ±0.6
Red Kidney	50.13	48.61	33.27	44.00	15.4 ±0.6
Early Bluff Cow Peas	15.31	62.87	12.78	30.32	10.6 ±0.5
Geismar			25.78	25.78	9.0 ±1.0

*The probable errors are asked for by experiment station workers generally, and are given here in connection with the yields in bushels per acre. They indicate that these results are expected to be correct within a bushel either way.

The results are expressed as percents of Robust and show that the Robust produces one and a half times that of the highest yielding commercial variety in the series. The results also show that the other selections of 1908 were inferior to Robust. The varietal testing work was discontinued at this point because the Robust variety had demonstrated its superiority so conclusively and because the other work demanded the use of all land then available.

DIFFERENT STRAINS OF ROBUST.

The Robust (81302) that was used up to this point and distributed in 1915, was further selected in 1914, and tested in plant-rows in 1915. Five of these strains No. 40509, No. 40511, No. 40515, No. 40516, and No. 40520 were increased in 1916 and entered the varietal series in 1917.

Thus it happened that a new selection of Robust (No. 40511) became the check in the 1917-1920 yield series, and that other strains of Robust were included in that series to determine the relative yielding power of the different strains. The principal part of the new varietal series was composed of farmers' varieties from the bean sections.

The check in the 1912-1914 varietal series had been Robust (81302). As this was the Robust that was distributed in 1915 and has since been sold by the Michigan Crop Improvement Association, we wished to know the relative yielding power of the old strain (No. 81302) and the new (No. 40511).

This question arose in 1917 in connection with the inspection of and certification of the Robust beans. For this purpose the growers of pedigreed Robust (No. 81302) beans were requested to submit a sample of their beans to be planted in the College varietal series in 1918. These samples were grown in duplicate plats and each pair of results averaged. The results are expressed as percents of the new check (Robust No. 40511) and are as follows.

TABLE II.—PERCENTAGE RELATION BETWEEN THE OLD (81302) AND THE NEW ROBUST (40511).

Grower.	Address.	Per cent of No. 40511.
G. Richard Bogan	Rosebush	82.1 ±3.2
C. F. Dickinson	Springport	93.5 ±3.6
Olaf Nelson	Aloha	102.2 ±4.0
David Kuhn	Vicksburg	83.0 ±3.2
Wm. A. Stanton	Ithaca	91.4 ±3.6
Willis Wahl	Centerville	88.4 ±3.
Average of all except Nelson's strain		87.7 ±1.5

The Nelson strain is not the original No. 81302 but came from a later selection which appears to be similar to 40511. The results given in Table II are only the data from one year. The results obtained are so similar that one would have great confidence in the average. Statistical methods however show the probable error is only 1.5 percent. This informs us that true average yield lies between 86.2 percent and 89.2 per cent. If these are results from the same strain of beans, the individual determination should be within the range (86.2 and 89.2). However four of the five results lie outside of these extremes. This leads us to believe that these strains are not alike but possess different yielding power, although originally from Robust No. 81302.

Again, in 1918 individual plant selections were made from Robust (No. 81302) fields in Genesee, Oakland, Oceana, and Jackson counties. These selections were tested in the 1919 plant row series. After the results were obtained over one-half of the Robust plant rows were discarded as too poor to continue in the breeding work at the Michigan Experiment Station. Twenty-seven of the selection tested in 1919 were continued in the 1920 plats. Seventeen of the selections tested in 1920 were from Genesee county. The average yield of these 17 selections was 74.3±2.8 percent of the yield of the 40511 strain. One of these selections yielded 49.7 percent while more than one-half of them yielded less than 68 percent and only one selection yielded as much as our check (No. 40511). The other selections from farmers' fields gave similar results. This shows the Robust bean in the hands of farmers lacks uniformity, indicating that a mixture has occurred somewhere along the line, and that this mixture varies greatly in producing power.

To sum up, investigation shows that many of the varieties termed "Robust beans" in the hands of farmers are no better than the common commercial varieties grown throughout the country. This is due to two causes: first, the original strain of 81302 was not as good as our present strain. Second, the mixture of other varieties has lowered the yield of the 81302 strain. Growers with these strains of inferior value should change their seed for highly productive Robust of unmistaken origin. The Farm Crops Department will furnish information in regard to safe sources of seed of pure Robust. The results of the 1917-20 varietal series show that a new strain of Robust No. 40520 is yielding 13.4 percent above the check (No. 40511) and one and a half times the yield that has been obtained from Early Wonder. The No. 40520 strain will be increased during the summer of 1921, and will be available to pedigreed growers in 1922.

THE 1917-1920 VARIETAL SERIES.

In 1916, increased effort was made to obtain the better varieties of beans being grown in the bean sections of Michigan. Plant selections were made from several farmers' fields that fall, and other lots were obtained during the following winter from members of the Michigan Crop Improvement Association, seedsmen and others.

Thus in 1917, a new series of varieties was planted in a newly planned five year rotation, the rotation being a spring grain, clover (clover plowed under during the second season for wheat), wheat (clover is seeded in wheat and plowed under early in May of next season), beans, and corn. The plantings of any one year will include all of these crops.

The varieties of beans were drilled in rows 420 feet long, two rows being devoted to variety. Inside the edges, Robust No. 40511 was used to plant checks (each fourth plat) of the varietal series. The object was to determine the yielding power of the No. 40511 strain on each and every plat of the series, and to calculate the yield of each variety as a percent of the yielding power of Robust No. 40511.

TABLE III—BEAN VARIETAL SERIES 1917-1920—PERCENTAGE YIELD OF ROBUST NO. 40511.

Variety.	1917.	1918.	1919.	1920.	Average.	Bus. per A.	Days growing.	Percent Early Wonder.
Robust No. 40520	....	117.9±6.8	112.6±7.5	109.9±4.5	113.4±3.7	23.9± .8	102	152.3±5.0
Robust No. 40516	92.8±3.8	117.4±6.8	101.9±6.5	100.8±4.1	103.2±2.8	21.8± .6	102	138.6±3.8
Robust No. 40511	100.0±1.3	100.0±1.5	100.0±1.8	100.0±1.3	100.0±1.3	21.1± .2	102	134.2±1.7
Robust No. 40509	97.1±4.0	104.3±6.0	99.7±6.6	91.8±3.7	98.2±2.6	20.7± .6	102	131.9±3.5
Robust No. 40515	98.0±4.0	92.8±5.3	97.9±6.5	....	96.2±3.1	20.3± .7	102	129.2±4.2
Kimmel	82.3±3.3	72.6±4.4	88.8±5.9	94.5±3.8	85.4±2.2	18.0± .5	101	114.7±3.0
Crawford	80.6±3.3	75.7±4.4	80.5±5.3	85.2±3.5	80.5±2.1	17.0± .4	97	108.0±2.8
Hunter	86.5±3.5	75.2±4.3	77.2±5.1	82.2±3.4	80.3±2.1	16.9± .4	97	107.8±2.8
1000-1	....	80.9±4.6	78.5±5.2	78.6±3.2	79.3±2.6	16.7± .5	97	106.5±3.5
Booth	79.2±3.2	75.7±4.3	71.4±4.7	87.7±3.6	78.5±2.0	16.6± .4	97	105.4±2.7
Boyne	82.8±3.4	80.3±4.6	72.0±4.8	76.3±3.1	77.8±2.2	16.4± .4	97	104.5±3.0
Cornair	77.3±3.2	66.9±3.8	71.1±4.7	94.0±3.8	77.3±2.0	16.3± .4	97	103.8±2.7
Darling	86.0±3.5	68.3±3.9	68.4±4 5	85.6±3.5	77.1±1.9	16.2± .4	97	103.4±2.5
Armstrong	91.4±3.7	67.1±3.8	67.7±4.6	79.8±3.2	76.5±1.9	16.1± .0	98	102.7±2.5
Greiner	....	77.0±4.5	64.0±4.3	83.2±3.4	74.7±2.4	15.8± .5	97	100.3±3.2
Vermont	....	81.7±6.6	62.0±4.1	80.4±3.3	74.7±2.8	15.7± .6	97	100.3±3.8
Early Wonder	73.4±3.0	71.0±4.1	65.2±4.3	88.3±3.6	74.5±1.9	15.7± .4	97	100.0±2.5
Terry	65.1±2.7	81.8±4.7	75.0±5.0	74.9±3.0	74.2±2.0	15.6± .4	97	99.6±2.7
Mexican Tree	74.5±3.0	65.0±3.7	64.4±4.3	90.2±3.7	73.5±1.9	15.5± .4	100	98.7±2.5
Keach	....	66.2±5.4	71.9±4.8	82.2±3.3	73.4±2.6	15.5± .6	97	98.5±3.5
Bad Axe	77.4±3.2	75.5±4.3	67.4±4.5	63.0±2.6	70.8±1.9	14.9± .4	97	94.9±2.5
Cranberry	....	68.8±4.0	34.0±2.3	....	51.4±2.3	10.8± .5	102	69.0±3.1

Table III shows the yields of the 1917-1920 varietal series expressed as percents of No. 40511. An average is taken of the results on each variety, obtained in the different years. The next column shows these results based on the average yield of the No. 40511 strain during these years. These results are low because of a poor crop in 1918, in spite of the fact that the No. 40511 strain yielded 31.48 bushels per acre in 1920.

Another column shows the average number of days that these beans require, between planting and harvest. The varieties fall into two classes, viz., late and early varieties. There are three varieties that are as late as Robust, but yield much less, and therefore are not worth considering.

The Robust selections that were included in the varietal series are all considerably higher in yield than the earlier varieties. There are only five days' difference between these classes. The problem is, does the farmer need an early variety, or could he plant the Robust bean a week earlier and have them ripen in good season.

The Early Wonder is the best known and most widely grown of the earlier class of beans. The last column expresses the results obtained in the form of percents of Early Wonder. This shows considerable variation (or a range of 12.8 percent), among the earlier varieties. The Crawford and Hunter are just as early as Early Wonder and yield 8 percent more beans. If there is a need for these early beans the highest yielders should be used. For this reason the Crawford and Hunter beans should be tested in those sections of the State where earliness is a factor in ripening.

The Crawford comes from Breckenridge, Gratiot county, and the Hunter comes from Sandusky, Sanilac county.

When we come to compare Early Wonder with Robust No. 40520, it is observed that the latter has produced on the average of one and a half times as many beans per acre as the Early Wonder.

The 40520 strain will be used as the check in a new varietal series beginning 1921. Of the beans listed in Table III only Robust No. 40511, and No. 40520 will be included. All other varieties will be dropped. The new strains entering the varietal series, originated from breeding work running back eight years, and from individual plants, selected out of farmers' fields in 1918.

THE BEAN AND ITS SURROUNDINGS.

The bean is one of the most sensitive crops to its surroundings. To have a good crop, there must be an abundance of available plant food, and a suitable temperature for rapid development at the time that the beans are planted. For best results the bean plant must not be retarded in growth. The best location is a clover sod plowed down in the fall or early in the spring and thoroughly worked, up to bean planting season. The seed bed should be thoroughly fitted before the crop is planted. Weeds are thus more easily controlled, and available plant food prepared for the seed. The seed should be clean, free of beans carrying blight and anthracnose, and also of immature and damaged beans.

The time of planting Robust is very important. A good harvest time should be considered at planting time. The crop requires a hundred days between planting and harvest. Middle September is usually a good time to harvest and cure the beans. By the first of October there is a greater danger that frosts and storms may injure the crop. For this reason Robust beans should be planted during the first week of June or earlier, if the ground is well prepared and warm enough for immediate germination. If planting of Robust is delayed until much after the middle of June, early frosts and storms may injure the crop.

Care must be taken not to pull the beans too soon. Leaves hinder curing and in wet weather will hold a surplus of water. In the case of the Robust, the leaves may be safely allowed to drop entirely before pulling. In the case of Early Wonder and beans of its class, the leaves will not all drop off, but should be nearly gone at harvest time. The defoliated crop can now be quickly pulled, cured and housed for threshing, with little danger of being discolored. Beans that are pulled with their leaves on, do not cure easily and may be badly discolored.

RATE OF SEEDING.

The rate of seeding has proved to be a very important factor in relation to yield.

TABLE IV—RATE OF SEEDING—RESULTS OBTAINED WITH NO. 40511 ROBUST.

Pounds per A.	1917.	1918.	1919.	1920.	Ave.	Bu. per A.	Diff. in bu.
20	83.6±3.3	66.0±3.6	70.7±4.4	84.9±3.3	76.1±1.8	16.1±.4	2.9
30	92.2±3.6	75.8±4.2	97.5±6.2	95.3±3.7	90.2±2.3	19.0±.5	2.1
40	100.0±1.3	100.0±1.5	100.0±1.8	100.0±1.3	100.0±1.3	21.1±.3	.2
50	95.7±3.7	....	106.4±6.7	100.9±3.9	101.0±2.8	21.3±.6	.1
60	89.4±3.5	....	113.1±7.0	101.1±3.9	101.2±2.9	21.4±.6	....

Investigations were begun in 1917, to determine the best rate of seeding and were continued during the four years 1917-20. Plats wre planted in approximately 20, 30, 40, 50 and 60 lbs. per acre, in duplicate just as though they were planted with different varieties of beans. However the check variety No. 40511 was used in all cases.

The results in Table IV are expressed as percents of the yield obtained when 40 pounds of beans were planted per acre. An average is taken for the results obtained in the various years. These averages are expressed as bushels per acre in the next column. These results show an increase of 2.9 bushels per acre, between 20 and 30 pound rates, and 2.1 bushels per acre between 30 and 40 pound rates, but show that the grower would no more than get his seed back when planting more than 40 pounds of beans per acre. The results vary considerably in the latter result. 1917 shows a decrease in yield above 40 pounds, while 1919 shows good increases above 40 pounds. In 1920 the results are much the same as the average.

The following calculation interprets these results in terms of average distance between beans in the row. A thousand Robust No. 40511 beans were found to weigh .5053 of a pound. According to this it would take 37.73 pounds of such seed to plant an acre, planting the seeds three inches apart, or 113.2 pounds of seed to plant the seeds one inch apart. If we let a equal number of inches between the seeds in the row, and x equal pounds per acre, ax equals 113.2, or the product of the distance between beans in inches and the seeding in pounds per acre, equals 113.2. Forty pounds per acre indicates that the beans were planted less than three inches apart on an average.

CONCLUSION.

1. The Robust has no competitor at the Michigan Station when yield is considered.
2. The Robust is not an early bean, but as early as a number of varieties now grown in the State.
3. The Robust should be planted by the first week in June.
4. When earliness is the determining factor it may be well to try Robust on a small scale, but plant it early.

5. Forty to forty-five pounds (approximately 21 to 24 qts.) of seed planted to the acre give the greatest returns from seed.

MICHIGAN AGRICULTURAL EXPERIMENT STATION AVAILABLE PUBLICATIONS ON BEANS

Experiments on the Control of Bean Anthracnose and Bean Blight
Technical Bulletin No. 38

Some Bean Pointers
Extension Bulletin No. 6

Free copies may be had upon request to Director R. S. Shaw, East Lansing, Michigan

DEPENDABLE MICHIGAN CROP VARIETIES.

Special Bulletin No. 109.

J. F. COX.

THEIR DEVELOPMENT AND DISTRIBUTION.

Crop varietal tests held in a large number of communities show that a great number of crop varieties of varying quality and yielding ability are being grown. If all farmers in any one neighborhood were to adopt the best varieties as their standards, increased yields would be secured and a more uniform and superior market grade produced.

For over forty years the Agricultural Experiment Station of the Michigan Agricultural College has conducted tests of varieties and carried on varietal improvement work. In the early days of this work new strains were distributed directly from the College and in many instances became mixed or "run out" in a relatively short time. During the past ten years there has developed a system of introduction of new varieties from the Experiment Station to the farmer through the Michigan Crop Improvement Association. This organization of seed growers can be joined by any farmer or seed grower in Michigan. The pedigreed varieties distributed from the Experiment Station and placed in the hands of growers through the agency of the Association, are inspected in the field, and sold under certification. This plan insures the source, variety, and condition of the seed at date of sale. In addition, there is a large movement of this seed of improved varieties from farm to farm. Most of the Michigan seed companies, dealing in field seeds, list in their catalogs and distribute widely, seed of varieties which originated at the Michigan Agricultural Experiment Station.

In addition to trade within the State, there has developed an extensive out-of-state trade, both wholesale and retail with such varieties as the Rosen rye, Red Rock wheat, Robust beans, and Wolverine, Worthy, and College Wonder oats.

Briefly outlined, the plan for accomplishing (1) the development, the testing, and the increase under inspection and (2) the sale of seed of improved varieties in Michigan is as follows:—

THE MICHIGAN AGRICULTURAL EXPERIMENTAL STATION, FARM CROPS DEPARTMENT, TESTS AND DEVELOPES VARIETIES

VARIETAL TESTING.

Extensive varietal tests of all major crops, including standard and new varieties, are maintained at the Experiment Station at East Lansing, at the Chatham Agricultural Experiment Sub-station, Upper Peninsula, and also at numerous points over the State on a co-operative basis.

PLANT BREEDING.

Pure-line selection and hybridization work with practically all crops adapted to Michigan is carried on by the Experiment Station plant breeders. The following varieties as listed and released by Professor F. A. Spragg, Plant Breeder, have been contributed by the plant breeding work of this Station during the past ten years: Worthy oats, 1911; Rosen rye, 1912; Red Rock wheat, 1913; Michigan Winter barley, 1914; Robust beans, 1915; College Wonder and College Success oats, 1916; Wolverine oats, 1917; Mich-Two-Row and Michigan black barley, 1918; and Michigan hardy (Hardigan) alfalfa, 1919.

CORN IMPROVEMENT.

The local adaptation of varieties is established by varietal tests. Field selection and intensified selection by the ear-row method is carried on at the Experiment Station and at points over the State with leading varieties. In lower Michigan counties the Duncan, Silver King, Folks White Cap, and Murdock corn are standard varieties; in central Michigan the Golden Glow and Pickett; and in northern Michigan the Early Golden Glow and Early Pickett.

Large increase fields on the Station farm make possible rapid and safe distribution. Properly handled increase fields are highly important in securing effective distribution of new varieties.

EXTENSION DIVISION AIDS IN DISTRIBUTION.

Extension specialists and county agents aid in securing wide-spread use of varieties of proved worth. Cooperative variety tests, planted by Crops specialists, are visited by numerous farmers led by county agents. The strength of the Michigan Crop Improvement Association is due largely to the efforts of Extension men and county agents working with able farmers.

THE MICHIGAN CROP IMPROVEMENT ASSOCIATION INCREASES VARIETIES UNDER INSPECTION.

(Secretary, East Lansing, Mich.)

This is an organization of Michigan farmers and seed growers who are interested in crop improvement through growing better varieties and the use of better cultural methods. A number are interested in the commercial production of high-grade seed. The association functions as follows:

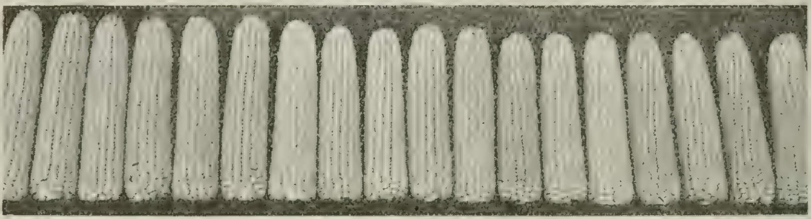
(1) Seed of improved varieties is distributed to members from the Farm Crops Department increase plats or other accepted sources.

(2) Records of distribution and transfer of varieties are kept by the Secretary.

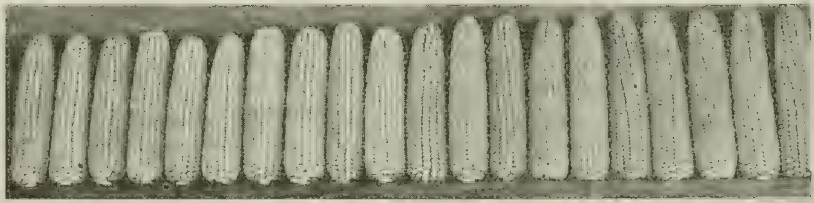
(3) Field inspection and threshed grain inspection is supported by the Association under the leadership of the Farm Crops Department.

(4) Certification of the seed which attains the required high standards is made by the Certification Committee. Certification is based on reports submitted by inspectors.

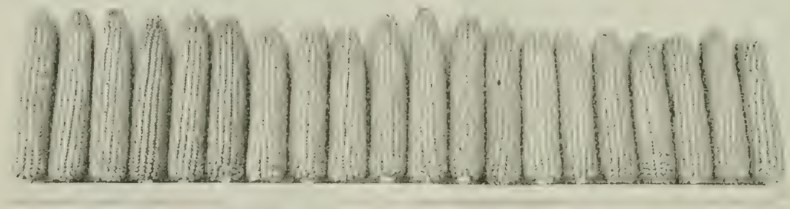
With the organization of the Michigan Farm Bureau Seed Department



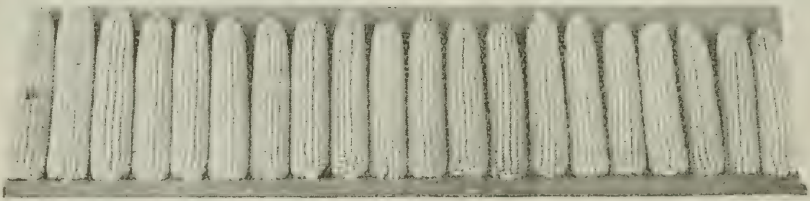
Early Silver King



Pickett Yellow Dent



Golden Glow



Duncan Yellow Dent

Standard Michigan Corn Varieties.

FIG. NO. 4. SOME STANDARD MICHIGAN CORN VARIETIES

The Early Silver King and Duncan are well adapted to Southern Michigan. The Golden Glow and Pickett are widely distributed, and adapted strains are grown in southern, central and northern corn growing sections.

the distribution of seed of high yielding varieties was placed on an even more effective basis, by officially designating that organization as an official sales agency of the Michigan Crop Improvement Association. The Farm Bureau Seed Department, which is equipped for the cleaning and handling of seed, has branch organizations in nearly all Michigan counties.

HIGH YIELDING VARIETIES PROPERLY HANDLED ON ADAPTED SOILS GIVE GREATEST PROFITS.

It is an undisputed fact that the selection of good seed of high yielding varieties is one of the most important factors in securing a high yield per acre at less cost per bushel in production. When crop prices are high, best varieties are usually in the strongest demand. As a matter of fact, high yielding varities are of equally great importance to the individual farmer when crop prices are low, since by growing improved strains the production cost per bushel is materially lessened.

In addition to growing good varieties it is important that properly treated seed be planted on adapted soil, properly prepared. The early plowing and thorough fitting of seed beds will increase yields. The date of planting various crops is also an important factor in determining yield. There is a marked tendency to plant wheat and rye too late in the fall and oats and barley too late in the spring.

Acid phosphate and other commercial fertilizers high in phosphorus pay large profits when rightly used, particularly on grain and cash crops. The use of lime is essential in securing good stands of alfalfa and clover in many Michigan districts. The growing of crops in proper rotation, with adequate applications of ground limestone or marl, manure, and phosphate fertilizers applied during the rotation, generally build up the land.

This brief circular does not aim to discuss the above questions in detail, but aims to emphasize the necessity of growing good varieties, under adapted conditions.

CORN VARIETIES.

Owing to the great variation of climatic and soil conditions in Michigan, it is of importance that corn varieties be grown only in regions to which they are adapted. Numerous variety tests throughout Michigan combined with a number of years' observations, have indicated the approximate sectional distribution of corn varieties, as shown by the accompanying varietal adaptation map—Figure No. 5.

It is highly important that seed be carefully selected in the field and properly stored. Seed resulting from three years of careful ear-row selection work at the Michigan Experiment Station with the Duncan, Golden Glow and Duncan-Golden Glow Cross will be released in quantity from the Michigan Experiment Station increase fields in the spring of 1922, chiefly through the Michigan Crop Improvement Association for increase in a large way.

Methods of selecting and caring for seed corn are dealt with in detail in the Michigan Experiment Station Bulletin No. 289, "Corn Growing in Michigan."

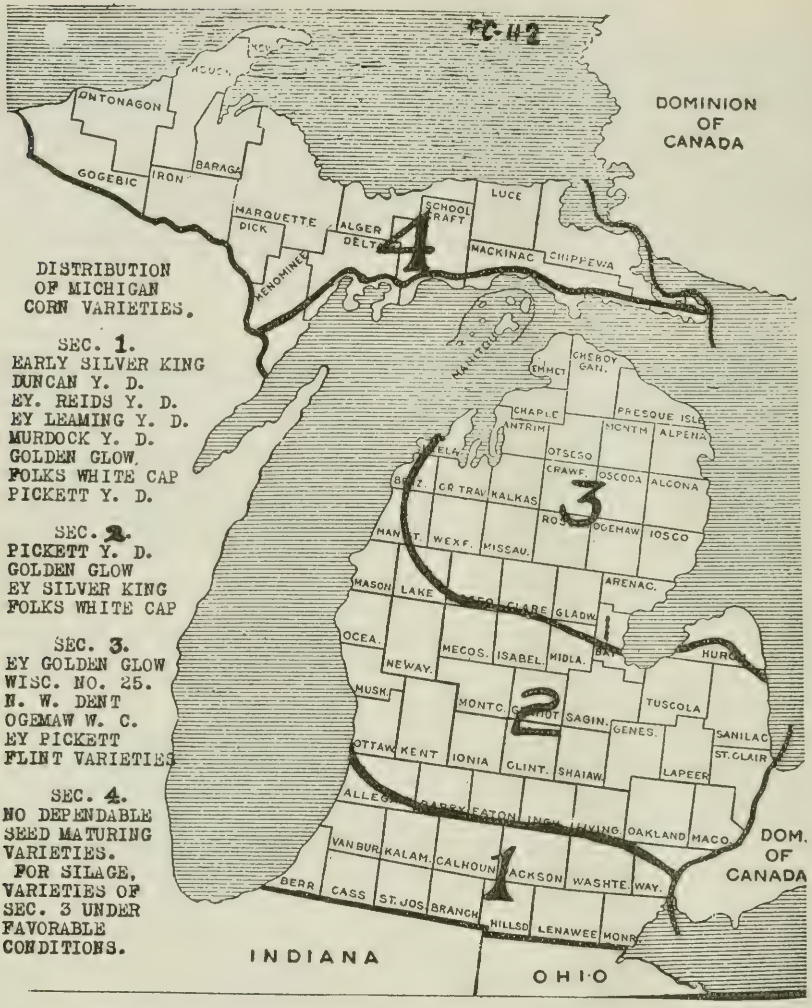


Fig 5. Map indicating approximate sectional adaptations of leading Michigan corn varieties.

County Agricultural Agents and the Farm Crops Department of the Michigan Agricultural Experment Station are in position to give information concerning varieties and source of dependable seed or established corn growing sections.

PICKETT YELLOW DENT.

The Pickett Yellow Dent is one of the oldest and best established varieties of Michigan. The ear is cylindrical and slightly tapering, measuring from seven to nine inches in length. It is adapted to southern and central Michigan. Very early strains are available for northern Michigan.

EARLY SILVER KING.

The Early Silver King is a white variety introduced into Michigan from northern Iowa, where it originated, and also from Wisconsin, where it has been widely distributed after selection and adaptation, as Wisconsin No. 7. The ear is usually from eight and one-half to nine and one-half inches in length. It ranges in season from 100 to 130 days. This variety is well known as a grain variety in southern Michigan—Section 1, and for silage purposes in Section 2. An early strain, which matures grain, is also available for Section 2.

DUNCAN YELLOW DENT.

The Duncan Yellow Dent was developed in southwestern Michigan, in St. Joseph county. It is a yellow dent variety and is both a vigorous grain producer and silage corn. In southern Michigan it is grown chiefly for grain, and in central Michigan is a good silage variety. Early varieties are being developed for central Michigan—Section 2.

THE GOLDEN GLOW VARIETY.

This yellow dent variety was introduced from Wisconsin. It is a vigorous grower of wide adaptation. The ears are of a golden yellow color, slightly tapering, from seven to nine inches in length. Strains of Early Golden Glow have been produced in Section 1, 2 and 3. Early Golden Glow—Wisconsin No. 12 and 25 are well adapted to northern Michigan corn growing districts.

FOLKS WHITE CAP.

This variety was developed by Mr. William Folks of Hanover, Jackson county. It is an exceptionally uniform white cap variety, which gives good yields in southern and south central Michigan. It has a vigorous stalk and is appreciated for both grain and silage purposes.

LAWRENCE YELLOW DENT.

This variety was developed at Decatur, Michigan. It is a yellow dent variety, well adapted to southwestern Michigan. The ear ranges from eight to nine and one-half inches in length.

MICHIGAN YELLOW DENT.

This variety, developed in Jackson county, is grown chiefly in southwestern Michigan. The ears are from eight to nine inches in length, and the kernels are of medium depth and medium indentation. This type is dependable in yield and adaptation in southern Michigan counties.

PRIDE OF MICHIGAN.

The Pride of Michigan is a yellow dent variety of long standing in southern Michigan. The type is thoroughly acclimated in southern Michigan, and strains which mature safely are established as far north as Saginaw county. The color is light golden. The ears range from eight to ten inches in length.

NORTHWESTERN DENT.

This is an early variety of corn adapted to northern Michigan corn districts—Section 3. The color is reddish with pale caps. The ears are small, and the kernels medium depth.

OAT VARIETIES.

The Wolverine oat has proved to be the highest yielder in the College oat variety tests. It is a pedigreed variety, developed at the Michigan Agricultural Experiment Station, and apparently widely adapted. This variety is a white, open panicle, oat, maturing in from 85 to 90 days.

The Worthy oat is a heavy yielding, stiff strawed, open panicle white oat, widely grown throughout lower Michigan during the past ten years, requiring 85 to 95 days. It was developed at the Michigan Agricultural Experiment Station from a pure strain selection. It is highly esteemed on heavy soils.

The College Wonder ranks second to the Wolverine in yield. It is an open panicle, white oat, requiring from 85 to 95 days to mature.

Special Bulletin No. 101 "Oats in Michigan" gives further information regarding varieties and oat growing.

WHEAT VARIETIES.

The Red Rock wheat is an excellent quality, high yielding, bearded red winter wheat. It is well adapted to the fertile loams and clay loams throughout Michigan. In milling quality it is superior to other soft red winter wheats, grown in Michigan.

Egyptian and Nigger are hardy red wheats of known worth.

The American Banner is a pure-strain selection of superior yielding and milling quality. It is a white beardless variety.

Dawson's Golden Chaff is a widely grown white beardless wheat of established merit. (Michigan Experiment Station Bulletin—Circular No. 31 "Red Rock Wheat" and Circular 34 "More Wheat for Michigan").

BARLEY VARIETIES.

The Wisconsin Pedigree is the highest yielding and most dependable of the six-row bearded types. It is a pedigreed variety, originally distributed by the Wisconsin Experiment Station.

The Michigan-Two-Row barley is a two-row type, developed at the Michigan Experiment Station. It yields highest on the Station plats and has given satisfactory results in many Michigan barley sections.

Michigan Black Barbless, or Smooth Awn barley is a dependable yielder, it gives a comparatively better growth. The beards are smooth and hence there is no inconvenience in handling this crop. It can be fed from the shock, or straw can be used for feed or bedding without causing irritation to livestock.

RYE.

The Rosen rye is outstandingly the best variety for Michigan. It was distributed from this Experiment Station in 1912 and since that time has been widely distributed, not only throughout Michigan, but other rye growing states. It is essential that pure Rosen be secured, since rye crosses freely in the field. Rosen is characterized by an exceedingly well filled head and large greenish kernel.

The Rosen rye is fully dealt with in Special Bulletin No. 105, Michigan Experiment Station, "Rosen Rye."

ALFALFA.

Alfalfa seed grown in Montana, northern Idaho, and North and South Dakota, is best suited for growing in Michigan. Occasionally during favorable seasons a small amount of Michigan grown seed is produced. This seed is highly desirable if in good condition. Seed produced from strains which are adapted to northwestern winters will produce stands which will come through Michigan winters successfully. The Grimm, Baltic, and Cossack are the best varieties. These varieties are characterized by their hardihood and their tendency to produce branching crowns close to or beneath the surface of the ground. There is a marked tendency also for the root system to branch. In the case of the Grimm and Baltic, flowers of variegated colors, whitish, blue, purple, and blends of these colors develop. Cossack alfalfa develops variegated blossoms of yellowish, white, blue, purple, and various blends. The above varieties do not winter kill as badly as the straight rooted, high crowned, purple flowered common alfalfa.

Common northern grown alfalfa, produced in the states above mentioned also gives good results in Michigan. They are not quite as hardy and enduring as the Grimm, Baltic, or Cossack. It is highly important that the source of seed be known in buying alfalfa.

A full discussion of alfalfa growing is given in the Michigan Experiment Station Special Bulletin No. 97, "Alfalfa in Michigan."

BEAN VARIETIES.

The Robust bean is a high yielding white pea bean which was developed at the Michigan Experiment Station. It is resistant to Mosaic, and is not as badly affected by blight and anthracnose as are many other varieties. It should be planted early in the bean planting season, since it is somewhat later in maturing than the common pea beans.

The Early Wonder is a very early strain of white pea bean, adapted to planting under climatic conditions which do not favor the proper maturing of the Robust.

For detailed information regarding bean varieties and bean growing secure Extension Bulletin No. 6, and Experiment Station Special Bulletin No. 108, Michigan Agricultural College.

SOYBEANS.

Professor C. R. Megee of the Farm Crops Department, Michigan Agricultural College, has listed the following varieties of soybeans as being of the most value:

Manchu—A very high yielding variety for both grain and forage. In variety tests conducted at this Experiment Station in 1919 and 1920, the Manchu gave the highest yield of hay. Plants are erect and mature in approximately 110 days, pubescence tawny, and flowers purple. Seed are medium size and straw yellow with slate black seed scar.

Ito San—Almost as good a yielder as Manchu and the most widely grown variety in Michigan. It is considered one of the best early varieties in the corn belt. Plants are erect, maturing in 110 days, pubescence tawny and flowers purple. Seed are straw yellow with a pale seed scar (lighter than seed coat) with a small reddish brown spot (micropyle) near one end of the scar.

Early Brown—Plant characteristics cannot be distinguished from Ito San. Seed of light brown color and medium size.

Black Eyebrow—Very similar to the Ito San in plant characteristics and time of maturity. Seed are easily distinguished by having an olive green underbody with dark saddle.

Hollybrook—One of the best mediums late maturing varieties, maturing from 125 to 135 days. Pubescence gray and the flowers white. Seed are straw yellow with a light brown seed scar, and are smaller than above mentioned varieties and much more flattened.

Early Black—For northern Michigan the Early Black is better adapted than the varieties above listed, being earlier in maturing. This is a black seeded variety. Due to its earliness the plant does not grow very tall nor rank.

Soybean culture is dealt with in Special bulletin No. 100, Michigan Experiment Station.

CLOVER.

Michigan grown red, alsike, and mammoth clover is more dependable than imported seed, much of which may have been produced in mild climates and is hence susceptible to winter killing.

SWEET CLOVER.

Michigan grown white blossomed biennial sweet clover gives best results for hay, pasturage, and soil improvement as compared to other biennial types. (Circular Bulletin No. 46, Michigan Agricultural Experiment Station, East Lansing.)

The yellow blossomed sweet clover (biennial) is slowly gaining favor for pasturage purposes (Michigan Experiment Station, Circular No. 46 "Sweet Clover").

HUBAM CLOVER.

Hubam clover—annual-white sweet clover—makes its entire growth in a single season. The seed is apparently identical in appearance to the biennial sweet clover seed, and it is therefore important that field-inspected and certified seed produced in Michigan be grown.

In 1921 thirty bushels of seed, at that time selling on the market from $5.00 to $20.00 per pound, was distributed to Michigan farmers and seed growers from the Farm Crops Department increase plats, through the Michigan Crop Improvement Association, at $1.00 per pound for increase purposes and ten bushels used in experiments to determine the real value of this new crop (Circular Bulletin No. 45, Michigan Agricultural Experiment Station, East Lansing).

VETCH.

Hairy vetch or winter vetch is grown for seed purposes to a greater extent in Michigan than any other state. Michigan grown seed should be demanded.

BUCKWHEAT.

The Japanese is conceded to be the highest yielding type. It is a large black seeded variety and makes the largest growth in the field. The Silver Hull and Gray are smaller types and do not make quite as large a growth.

DEPENDABLE CROP VARIETIES FOR MICHIGAN.

Oats

*Wolverine. *Worthy. *College Wonder.

Barley

*Wisconsin Pedigree. *Mich-Two-Row. *Michigan Black Barbless.

Corn

Southern Michigan	Central Michigan	Northern Michigan
*Early Silver King.	*Early Silver King.	Northwestern Dent.
*Golden Glow.	*Golden Glow.	*Early Golden Glow.
*Duncan.	*Pickett.	Early Pickett.
*Folks White Cap.	*Folks White Cap.	Wisc. No. 25.
Murdock.		
Pickett.		

Wheat

Red		White
*Red Rock.		*American Banner.
Shepher's Perfection.	Lancaster.	Gold Coin.
Economy.	Champion.	Dawson's Golden Chaff.
Egyptian.		
Nigger.		

Rye

*Rosen.

Soybeans

*Ito San *Black Eyebrow *Manchu

Buckwheat

Japanese Silver Hull

Millet

Golden Hungarian Common

Beans

*Robust *Early Wonder

Sorghum

Early Amber

Alfalfa

Northwestern-grown Grimm, Baltic, Cossack, and Common, also Michigan grown seed.

Clover

*Michigan-grown Red, Mammonth, and Alsike.

Vetch

*Michigan-grown Hairy vetch (winter)

Sweet Clover (Biennial)

*Michigan-grown White Blossomed.

Hubam Clover (Annual White Sweet Clover)

*Michigan-grown Hubam

Potatoes

Late—Petoskey, Rural New Yorker, Sir Walter Raleigh, and Green Mountain.

Early—Early Ohio, Irish Cobbler, Bliss Triumph.

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*Seed inspected and certified by the Michigan Crop Improvement Association.

**Inspected seed of standard stock produced by the Potato Growers Association—H. C. Moore, East Lansing, Secretary. Bulletin No. 5—Horticultural Department gives varietal recommendations, and Bulletin No. 7 gives information regarding potato culture.

FOREWORD.

A great deal has been accomplished and many changes have taken place at the Upper Peninsula Experiment Station at Chatham, since the publication of the last special report in 1918, as Special Bulletin No. 90. The present report, Special Bulletin No. 110 is an attempt to present to the people of the Upper Peninsula the improvements made and also a summary of the work conducted and the results obtained by the Experiment Station workers at Chatham for the past two years.

Formerly all of the work at the Station including land clearing, crop and livestock production, has been handled by the Superintendent. During the past two years, however, the Michigan Experiment Station has been in a position to place two additional specialists at the Upper Peninsula Station to be of service to the farmers in that portion of the State.

D. L. McMillan, Superintendent, has general supervision over all of the Station work and specializes in the livestock production, a report of which is given under "Animal Husbandry." J. E. Kotila has charge of work connected with diseases and insect control on potatoes. The section of this bulletin entitled "Potato Disease Investigations" is a report of his work at the Station. G. W. Putnam, the plant breeder, has charge of all farm crops experimental work and the report of his work is given in the section entitled "Farm Crops". Mr. Putnam was largely instrumental in the assembling and editing of this bulletin.

All farmers and others interested in the agriculture of the Upper Peninsula should profit by this report and feel that the Station belongs to them and that the work conducted there is for their benefit. We ask the cooperation of all those interested in the development of northern Michigan.

E. B. HILL,
Assistant to the Director.

SPECIAL REPORT OF THE UPPER PENINSULA AGRICULTURAL EXPERIMENT STATION.

Special Bulletin No. 110

BY D. L. MC MILLAN AND G. W. PUTNAM.

ANIMAL HUSBANDRY.

The livestock of the Upper Peninsula is a fair index to the advancement of agriculture in that territory. The development of the new cut-over land will be successful largely in proportion to the extent of development of the dairying, sheep raising, or of some other livestock enterprise. The sections already developed, with farming practices well established depend upon livestock production as an important factor in utilizing crops products and in maintaining fertility.

One of the purposes of this Station is to conduct experiments which will aid in guiding the development of livestock farming along the most profitable lines. The Station is fortunate in having substantial livestock buildings and foundational herds and flocks to carry out the many experiments needed in the development of breeding stock and livestock management for farmers of northern Michigan.

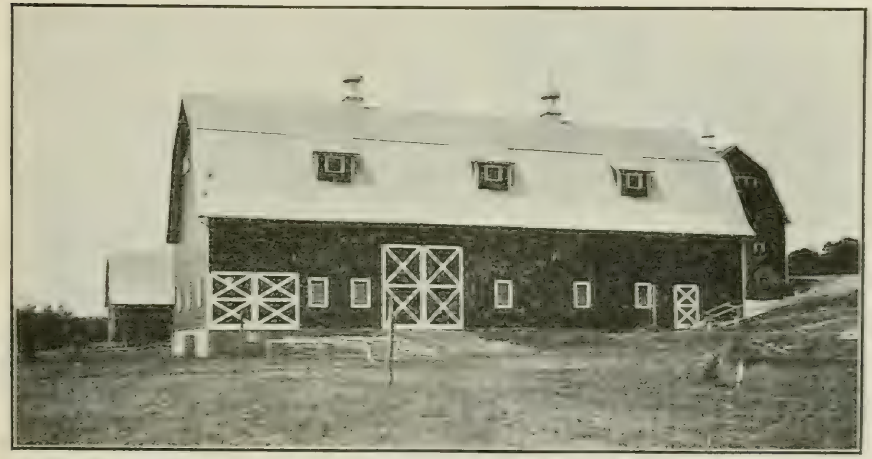

Fig. No. 2. The New Horse Barn. The Station has excellent live stock buildings.

DAIRY HERD.

The dairy herd, under careful management, has improved consistently. it contains a total of twenty-six head of Holsteins, comprising one herd bull, ten cows three years old or over, four two-year heifers, three yearling heifers and eight young calves.

The average production of the herd per head for 1919 was 11,851 pounds of milk, and for the year 1920 was 12,990 pounds of milk. This average is for all animals that have completed one lactation period. The yearly milk records of the herd for the last completed lactation period were as follows:

No. 17—16,895 pounds
No. 19—14,974 "
No. 18—16,352 "
No. 21—11,899 "
No. 22—13,317 "
No. 23—11,252 pounds
No. 26— 9,530 "
No. 30—11,647 "
No. 31— 7,771 "
No. 37—15,671 "

This production has been made under conditions similar to those on any good dairy farm with no special effort being made to make high individual records. For a short time after freshening, the highest producers were milked three times daily until their udders became in good condition to stand milking but twice.

No. 31 was seriously handicapped on account of trouble with her teeth. The highest daily record was made by No. 18 giving ninety pounds of milk, which tested 3.2 percent butter fat. She also produced in the month of March 2215 pounds and in April 2515 pounds of milk.

In the summer the herd received most of their feed in the pasture. During the worst of the fly season, however, considerable grain was fed to hold up production, and the cows were kept in the barn during the middle of the day in order to escape the flies.

Most of the products from the dairy are sold as whole milk and sweet cream in Marquette and Munising, only enough milk being separated here to supply skim milk for the pigs and calves. The surplus breeding animals have been sold to farmers in the Upper Peninsula.

Fig. No. 3. The foundation herd at the Chatham Sub-Station. This pure bred herd is contributing to the production records of many farm herds in the northern peninsula by furnishing many well bred male and female animals.

FEEDING TESTS FOR WINTER OF 1920-21.

Sunflower Silage vs. Pea and Oat Silage.

During the winter of 1920-1921 comparative results were observed on the use of sunflower silage vs. pea and oat silage. Eleven tons of pea and oat silage had been placed in the center of the silo with sunflower silage on the bottom and top of the silo. The same grain and hay ration was used with both types of silage and the same care given. The change from sunflower silage to pea and oat silage was made January 17th and the change back to sunflower silage was made on February 13th.

Careful milk records of the herd were kept with the following results:

Average daily total milk production for the last 15 days before changing from sunflowers to pea and oat silage was 484.6 pounds.

Average for the 27 days while being fed on the pea and oat silage was 483.8 pounds.

Average daily production for the first 15 days after making the change back to sunflower silage was 466.2 pounds.

The cows relished both types of silage about equally well, but owing to the bulkiness of the pea and oat silage they did not consume more than thirty-five pounds per head per day while they would take forty pounds of the sunflower silage.

Conclusions to be drawn from this comparative test would be that pound for pound the pea and oat silage is a trifle better than the sunflower silage. The sunflower silage, however, was about equal in palatability and in ability to produce milk when the animal is allowed to consume the quantity desired. From a standpoint of economy the sunflower silage has the advantage as it can be produced for less than half the cost of the pea and oat silage.

SHEEP.

The Station has been fortunate in building up a flock of sheep that is now in a position to furnish valuable breeding stock for farmers of the Upper Peninsula. In addition the flock is representative of the different breeds and grades so that they form the basis for many valuable experiments on flock management.

WINTER FEEDING EXPERIMENTS 1918-19.

The feeding tests were divided into two series: series A feeding tests with 70 ewe lambs: series B feeding tests with 150 breeding ewes.

Series A:—The ewe lambs were separated into two lots, and an experiment to determine the relative feeding values of barley versus corn in the ration was conducted.

Lot 1 was fed the ration composed of three parts barley, one part oats with a few roots, and clover hay.

Lot 2 was fed a similar ration, only corn was substituted for barley in the grain ration.

SERIES A. RATION EXPERIMENTS WITH EWE LAMBS.

For the 75 Day Period, Jan. 8th, 1919 to March 23rd, 1919, Incl.

	Lot I Barley 3 parts, Oats 1 part, Roots, Clover.	Lot II Corn 3 parts, Oats 1 part, Roots, Clover.
Av. Initial Weight	72.6 lbs.	71.8 lbs.
Av. Final Weight	84.3 lbs.	82.1 lbs.
Gain per Lamb	11.7 lbs.	10.3 lbs.
Av. Daily Gain	.1560 lbs.	.1386 lbs.
Av. Daily Feed Per Lamb		
Clover	1.95 lbs.	1.858 lbs.
Barley	.375 lbs.	
Corn		.375 lbs.
Oats	.125 lbs.	.125 lbs.
Roots	2.000 lbs.	2.000 lbs.
Total Feed per Lamb		
Clover	146.6 @ 1¼c lb.	139.35 @ 1¼c lb.
Barley	28.125 @ 2c lb.	
Corn		28.12 @ 3c lb.
Oats	9.375 @ 3c lb.	9.37 @ 3c lb.
Roots	150.000 @ ⅓c lb.	150.00 @ ⅓c lb.
Av. Cost per Lamb for 75 day period	3.18	3.37
Av. cost per lamb per day	.04	.05

The experimental evidence here submitted would indicate that ewe lambs would make just as profitable gains with barley in the ration as they would with corn. The average daily gain and the average daily feed consumed are more reliable indexes to the relative worth of these two feeds than are the cash values assigned. The cash value will fluctuate from time to time as the market demand fluctuates for these commodities. Another important angle to this experiment is the fact that only a very few, if any, Upper Peninsula farmers can produce corn for grain, while abundant crops of barley are grown in every section of the territory.

Series B:—The breeding ewes were separated into five lots and an experiment conducted to determine the relative values of silage, roots, bran, and dried beet pulp in the ration.

Lot 1 received silage, oats and hay.
Lot 2, received roots, oats and hay.
Lot 3, received bran, oats, and hay.
Lot 4, received dried beet pulp, oats and hay.
Lot 5, received only hay and was used as a check on cost of wintering.
Lot 1-4, received ¼ pound daily of oats and all the hay they would eat.

SERIES B. RATION EXPERIMENT WITH BREEDING EWES.

For the 75 Day Period, Jan. 8, 1919 to Mar. 23, 1919, Incl.

	Lot I Silage Oats Hay (Pounds)	Lot II Roots Oats Hay (Pounds)	Lot III Bran Oats Hay (Pounds)	Lot IV Dried Beetpulp Oats Hay (Pounds)	Lot V Check Hay (Pounds)
Av. Initial Weight	114.00	116.0	119.6	125.00	121.2
Av. Final Weight	119.7	125.6	125.4	131.6	122.3
Av. Total Gain per Ewe	5.7	9.6	5.8	6.6	1.1
Av. Daily Gain	.095	.16	.097	.11	.018
Av. Daily Feed					
Silage	1.76				
Roots		1.76			
Bran			.25		
Dried Beet Pulp				.25	
Oats	.25	.25	.25	.25	
Hay	2.35	2.90	3.7	3.82	4.20
Total Feed per Ewe.					
Silage	132.				
Roots		132.			
Bran			16.5		
Dried Beet Pulp				16.5	
Oats	16.5	16.5	16.5	16.5	
Hay	155.6	190.3	244.2	252.00	277.7
Feed cost per Ewe for the 74 day period	2.64	3.16	3.61	3.78	2.47
Av. cost per ewe per day	.03½	.04	.05	.05	.04½

The experimental evidence here submitted would indicate that 1½ to 1¾ pounds of silage or roots can well be added to the winter ration of the breeding ewe.

Of these one hundred fifty ewes, nineteen failed to breed. The remaining one-hundred thirty-one ewes gave birth to one hundred-fifty-two lambs. Of these, fourteen died during lambing time, and three during the summer.

In the fall of 1919, seventy-three lambs, consisting of wether lambs, cull ewe lambs and cull ram lambs, also forty-three ewes, were sold.

One very noticeable feature regarding the lambs, was the marked contrast between the wether and ram lambs, that had exactly the same chance for development. The wether lambs were fat and considerably heavier than the ram lambs at shipping time, and were worth about two cents a pound more on the market. This needs emphasizing as many farmers do not castrate the ram lambs. This means not only loss in weight, but a reduction in price per pound where lambs are past four months of age.

The flock sheared an average of seven and one-fifth pounds of wool. Directly after shearing the sheep were dipped, then turned to pasture. The lambs were docked and castrated when about two weeks old.

FLOCK MANAGEMENT FALL 1919 TO FALL 1920.

In the fall of 1919, two excellent rams, a Shropshire and a Hampshire, were purchased, and a good Rambouillet ram from the College at East Lansing was sent to this Station.

One hundred sixty-five ewes, four rams, six wether lambs and 15 ram lambs were put into winter quarters November 28, 1919. For the first month the ewes were given nothing but clover hay and they consumed about three and one-half pounds daily. Owing to the high price of hay the ration was changed to two and one-half pounds of hay and one-half pound of oats, this proved cheaper and the ewes did much better on this than on the straight hay. They carried through in excellent condition on this ration until about a month before lambing when the ration was changed to one-half pound of grain consisting of one part bran to two parts oats. They were also given about two pounds of rutabagas.

The lambs were fed what clover hay they wanted which was a little better than two pounds and for grain ration they received one-half pound of a mixture consisting of two parts cracked corn, one part bran, and one part oats, and one-fourth part oil meal. The ewes were in excellent condition at lambing time and 158 ewes gave birth to 197 lambs averaging about eight pounds each. Twelve of these died shortly after lambing. The flock sheared an average of 7.3 pounds of wool.

Fig. No. 4. Part of Station flock, 1920-lambs four months of age.

In November 1920 the wether lambs, cull rams and cull ewes were shipped to Chicago. A large percentage of the lambs again topped the market, weighing 78½ pounds. One pure bred ewe lamb was given as a prize for sheep judging at the Farmer's Round-Up and the best ram lambs sold to farmers as breeders.

FLOCK MANAGEMENT WINTER 1920-1921.

Two hundred sixty-six sheep consisting of 35 pure bred Hampshire ewes, 16 pure bred Rambouillet ewes, six pure bred Shropshire ewes, 124 cross bred ewes, two pure bred Hampshire rams, two pure bred Rambouillet rams, one pure bred Shropshire ram, five pure bred ram lambs, 75 ewe lambs and three wether lambs. The ewes were fed a ration of two pounds mixed hay, two pounds sunflower silage, and one-half pound oats. The lambs were given two pounds mixed hay, one pound sunflower silage, and one-half pound grain consisting of two parts cracked corn, one part bran, one part oats, and one-fourth part oil meal. They relished the sunflower silage and did well on it.

POULTRY.

Two breeds of poultry have been kept, the Barred Rocks and White Leghorns. No special experimental work has been done with them. In the spring of each year all eggs suitable for hatching have been sent out to farmers. In the fall and winter the best cockerels have been sold to poultry raisers of the Upper Peninsula for breeding purposes.

It is planned to expand the poultry work somewhat here at this Station in order to have more eggs and cockerels from high producing birds to sell to farmers. Farm poultry flocks are very profitable and more work should be done to encourage the keeping of high, winter laying strains.

HORSES.

In 1919, two draft teams and one general purpose horse were kept for farm work. In 1920 another team was purchased. These horses with a little extra hired horse labor during the rush of the spring's work have done the work at the Station. After completing the farm work in the fall of 1920 two of the teams were sold to lumbermen in order to reduce winter feeding expenses. They will be replaced the following spring.

HOGS.

The Station is keeping but one breed of hogs, Duroc Jerseys. They are one of the breeds best adapted to northern Michigan conditions. The herd consists of one aged boar, three yearling brood sows, and some shoats that are being fattened.

Several young boars and sows have been sold to farmers for breeding purposes. This stock is all especially well bred and it is hoped that the farmers will take advantage of the opportunity of getting a high class of breeding stock, rather than keeping the cull stock that so many of them are now using.

FARM CROPS.

The field crops of the Upper Peninsula are very diversified. This is the usual condition found in any comparatively new territory when its farming citizenship has developed from many widely varying parts of the country, and from people previously engaged in many commercial pursuits widely separated from actual farming conditions.

It is the function of the Farm Crops Section to perform basic crops experimental work and to serve as a clearing house for field crop information. Many practices in operation on the various farms of the Peninsula are eminently successful, while others pay little returns or are unprofitable. The Station is conducting many experiments in an attempt to establish the better crops varieties and cultural practices for the various sections of the territory. In addition, it is rendering a service in actual seed distribution of adapted varieties from its own fields.

GRAIN EXPERIMENTS.

Experimental grain work has been conducted along two main lines during the past two seasons. First, the testing of commercial and pedigreed va-

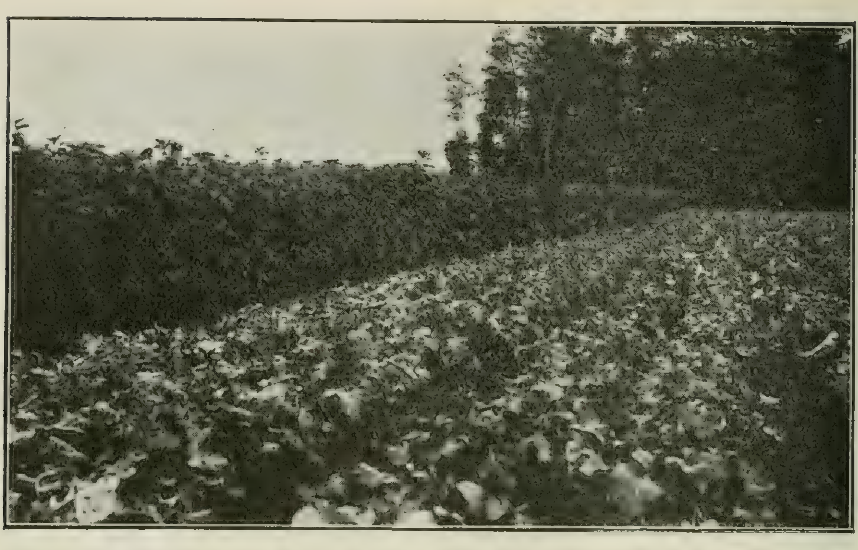

Fig. No. 6. Two important succulent winter feeds for the Upper Peninsula. Sunflowers have become an important silage crop in sections where corn is not adapted. Rutabagas are an essential requirement for successful winter feeding of dairy stock and sheep in the Upper Peninsula.

rieties of our common grains. Second, the development of pedigreed varieties for Northern Michigan. In old settled sections there are certain varieties which have come to be recognized as standard because farmers have grown them under varied conditions, and find that one year with another, they stand out as being superior to the average. In a comparatively new farming country, such as the Upper Peninsula, it would take years of development before any particular varieties would come to be universally recognized as the best. So it is our first problem to systematically test out and determine what particular commercial varieties, already in the hands of the farmers or seedsmen, or pedigreed variety already developed by an experiment station, most nearly meets the demands of the Upper Peninsula.

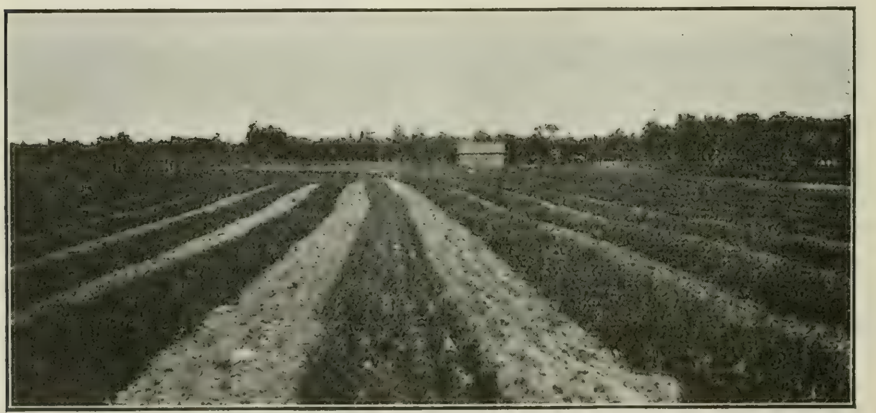

Fig. No. 7. In commercial variety testing each variety is drilled in beds six drill rows wide with an 18 inch alley between plats. Each fourth plat is a check to determine variation in soil fertility.

COMMERCIAL VARIETY TESTING.

In starting this work in 1919, the best varieties of oats, spring wheat, and field peas developed at the Experiment Stations of Michigan, Wisconsin, Minnesota and Canada, were obtained. A call was made to the Upper Peninsula farmers for their best varieties of these grains, but owing to the newness of the work, not many farmers' varieties were obtained in time to plant; a few, however, were entered largely through the efforts of the various Upper Peninsula County Agents. At the Farmers' Picnic, held at the Station in August, many farmers promised to send in samples, only a few of which have been received.

OATS.

The following points were observed on 27 oat plats, representing 18 different varieties:—Date of planting, date ripe, pounds per plat procured, yield in bushels per acre, and test weight per bushel.

The highest producing varieties grown in 1919 were the two early oats, Iowa 103 and the 60-Day. The highest producing medium late oats were Minota 512 from Minnesota and Wolverine from the main station at the Michigan Agricultural College. The early oats were ripe by August 1st, whereas the later maturing oats were not ripe until the middle of August. Since we received a very short rainfall for the month of July (.93 of an inch), it made the season more favorable for earlier oats than for late, because the earlier oats were ripening during this period and the later oats were setting and filling, and dry weather is more favorable to ripening than to development.

The high producing varieties grown in 1920, however, were the Wolverine, Worthy and College Success from M. A. C. The early varieties that were outstanding in 1919 did not yield within 25 percent ot the late oats in 1920, because of the more favorable weather for late oats. The rainfall for July was more nearly the rainfall of an average season (1.62 inches).

Fig. No. 8. On August 15th, 1919, Upper Peninsula County Agricultural Agents and their associated Extension workers, gathered at the Station to study the experimental work that was being carried on during the past season. This is an annual event.

SPRING WHEAT.

Data was taken in 1919 on fifteen plats of spring wheat representing ten different strains or varieties. Because of the exceptionally unfavorable season none of the varieties developed into wheat that would make good flour. Fifty-one pounds being the highest test weight per bushel obtained, although in bushels per acre some of the strains did very well, producing as high as twenty-two bushels. Because of the dry weather during July and a severe attack of rust, the wheat was of a very low quality. This condition of badly shriveled kernels in 1919, was true in general over that section of the Upper Peninsula in which the Experiment Station lies. A notable instance, however, is the fact that strains of Marquis gave better results than any other variety.

The work on spring wheat in 1920 was confined to the Marquis variety, because of its outstanding superiority over other hard spring wheat varieties. The influence of time of planting, was the subject for investigation in 1920. The experiment covered a range of planting dates from April 20th to June 7th by seven day periods. The black stem rust appeared in July and at harvest time all plants were so badly infested that none of them were harvested; however, the plats seeded prior to May 5th all gave a decidedly more uniform stand and more vigorous plant growth.

SPRING BARLEY.

Barley testing has been confined to the three varieties, Michigan Black Barbless, Michigan 2-Row and Oderbrucker. The black barley in 1919 and the Michigan 2-Row in 1920 gave the highest yield. There are several factors entering into barley production in northern Michigan that will require investigation for the best production of the crop.

Development of Pedigreed Varieties.

The second line of work with the small grains is the starting of the individual plant selections from which pedigreed varieties will be developed for the Upper Peninsula.

Sixty-five of these selection plats, representing as many different strains of the various small grains, were planted in 1919 in such a way that the plant resulting from an individual kernel could be selected. The grain coming from these individual plant selections were put into plant row series in 1920 and from the best of these rows, selections were made for planting in increase plats for 1921.

This type of crop improvement work takes time, but it is by this method that we will ultimately develop pedigreed varieties best suited to the needs of the Upper Peninsula. The better pedigreed strains developed will be tested out against the commercial varieties found best suited for Upper Peninsula conditions and the superior ones distributed to improved grain growers.

Fig. No. 9. Rod rows of pedigreed oats developed at the Station. Twenty-nine strains were tested in 1920.

WINTER WHEAT.

In making a study of the winter wheat crop in the Upper Peninsula it is impressive to note that two conditions are found, namely, in certain instances, soft red winter wheat is being produced of as good a quality and yield as is to be found anywhere in the State, in fact, the second prize winning sample in the Soft Red Winter Wheat Class at the Chicago International Grain and Hay Show, 1919, was won by Red Rock wheat, grown in the Upper Peninsula. This, in itself, speaks for the quality of wheat that can be produced. On the other hand, many fields visited were poor stands owing to the way in which they had been planted and handled, though of good quality they would not pay for harvesting, because of the poor stand.

On close examination, it is found that those farmers who are meeting with success in the growing of soft red winter wheat are those who make a special effort to have their wheat ground well prepared, usually sowing it on ground that has been summer fallowed and getting it planted fairly early, preferably the last two weeks in August. The ones who have met with the most failures are those who have removed some other crop and then hurriedly prepared the seed bed and sown their wheat rather late in the fall.

To try and check-up on just what influence preparation of seed bed and time of planting have to do with the success or failure of growing soft red winter wheat in the Upper Peninsula, a plat of land was laid off and summer fallowed in the summer of 1919. Incidentally this piece of ground was knee high with quack grass when first plowed under in June, and we will have the opportunity of seeing what effect summer fallow has in the ultimate control of quack grass. Twelve different plats about one week apart in time of seeding were sown on this fallow land. The first plat was sown on August 3th and the last one on November 2nd, representing the earliest and latest ates of practice planting. August 13th to 29th gave the better yield and quality of grain. A portion of this same plat of land was utilized for the time of planting test for spring wheat. This will give some data on whether winter or spring wheat is best to grow under Upper Peninsula conditions.

The 1920 spring wheat was completely destroyed by wheat rust so no direct comparison could be made.

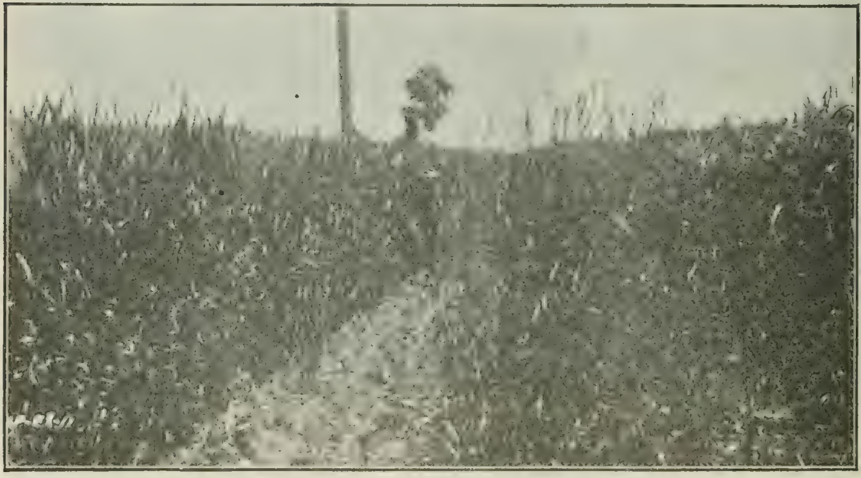

Fig. No. 10. Red Rock wheat on summer fallow ground planted August 29th, 1919. Winter wheat seeded between August 13th, to 29th gave the better yield and quality of grain.

RYE.

A test was put in to establish which was the better yielder Rosen, common winter, or common spring rye. The Rosen has proven to be superior in yield and quality. The work in the future will be confined to maintaining the purity and aiding in the distribution of this variety.

A plat was sown in an isolated section of the Station to the choicest head selected Rosen rye which could be secured. This plat was harvested to furnish seed for further increase of an ample supply of pure Rosen for distribution in the Upper Peninsula.

WINTER BARLEY.

A test plat was sown in 1919 to Michigan Winter Barley, about 90% of the plat winter killed. The variety is not adapted to the Upper Peninsula.

Fig. No. 11. A general view of the experimental plats in 1919.

FIELD RESULTS WITH IMPROVED GRAIN VARIETIES.

It has been the practice for the past few years for the Station to increase and distribute improved grain varieties. In the future this will form a part of the carefully worked out plan of the Farm Crops Section to distribute through the Upper Peninsula Michigan Crop Improvement Association members, in order to enable rapid increase of superior sorts for general farm distribution over the section.

BARLEY.

Eleven acres of Wisconsin Pedigreed Barley planted in the spring of 1919, produced only 16.2 bushels per acre. The dry weather of July was the diverting factor in production. This is just about one-third of a normal year's crop.

OATS.

Four and seven-tenths acres of newly broken land planted to Worthy Oats in the spring of 1918 produced 64 bushels per acre. A seeding of alsike clover with the oats produced a good stand.

ROSEN RYE.

Two acres of Rosen Rye planted at the rate of 1¼ bushels per acre in the fall of 1918 produced 20½ bushels per acre. (Several stumps in the field were not allowed for in figuring up production.) The acre production was slightly higher than here indicated.

FORAGE CROP EXPERIMENTS.

In outlining the initial projects, the chief problems considered were the finding of a high yielding and dependable silage crop and a successful annual hay crop. Peas and oats in the past have proven their dependability as a silage crop. Corn is a success where it can be grown. During the season of 1919 sunflowers were tested as a possible silage crop for northern Mich-

Fig. No. 12. Sunflowers. A new crop for northern Michigan.

igan. This crop is more resistent to frost than corn and often yields heavily under adverse weather and soil conditions. An estimated yield of 25 tons per acre of green forage was produced in 1919 on a one acre plot. This crop gives promise of being valuable as a silage crop when its culture and feeding value are more fully understood.

SUNFLOWERS.

In 1919 one acre was seeded on June 2nd by use of an ordinary grain drill, with three out of every four holes plugged, so that the rows were 24 inches apart, seeding 10 pounds of Mammoth Russian seed to the acre. The time of seeding, distance apart of rows and rate of seeding were arbitrarily selected, no data being available for our conditions.

In 1920, through inquiries from farmers throughout the State, we felt the need of more definite information about sunflowers and the following experimental work was conducted.

TIME OF SEEDING.

Plats were seeded with a grain drill, the holes being plugged to give the proper spacing of rows. Because of the varied condition of the field at this particular part, a check was seeded every plot, the plots being one-seventeenth of an acre in size.

DATA.

Date Planted	Lbs. of Seed per acre.	Distance between rows, inches.	Date harvested	Lbs. of green forage per plot.	Tons per acre.
Check May 26th	6	30	Sept. 20	1,720	14.6
June 2nd	6	30	Sept. 20	1,340	11.3
Check May 26th	6	30	Sept. 20	2,000	17.
June 9th	6	30	Sept. 20	1,290	10.9
Check May 26th	6	30	Sept. 20	2,400	20.4

The earlier seeding gave the better yield, it also gave the better quality of silage material.

DISTANCE APART OF ROWS AND RATE OF PLANTING.

DATA.

Date planted.	Lbs. of seed per acre.	Distance between rows inches.	Date harvested	Lbs. of green forage per plot.	Tons per acre.
Check May 26	6	30	Sept. 20	2,100	17.8
May 27	30	6	Sept. 20	1,745	14.8
May 27	15	12	Sept. 20	1,600	13.6
May 27	10	18	Sept. 20	1,500	12.7
Check May 27	6	30	Sept. 20	1,860	15.8
May 27	7½	24	Sept. 20	1,635	13.8
May 27	7	36	Sept. 20	1,620	13.7
May 27	6	42	Sept. 20	1,840	15.6
May 27	8	30	Sept. 20	2,165	18.4
Check May 27	6	30	Sept. 20	1,850	15.7

The rows at distances of 24 to 36 inches gave the best quality of silage. The rows under 24 inches gave small stalks which tended to lose their leaves at a premature stage while the 42-inch rows tended to produce heavy stalks that would reduce the quality of the silage. The 30 to 42-inch rows gave the heaviest yields and also required less seed per acre for a stand than did the closer plantings.

The results obtained from these experiments would indicate that rows from 30 to 36 inches apart seeded at from 6 to 8 pounds per acre will give the most satisfactory results for northern Michigan.

CULTIVATION.

In 1919 when the plants were about six inches high, they were thinned to a plant every 6 to 10 inches, otherwise receiving about the same culture as you would give corn. In 1920 none of the plats were thinned with a hoe, the idea being to determine a rate of seeding that would do away with any expensive hand labor, all plats were cultivated as for corn. A more perfect stand can be obtained by seeding a little heavy and then thinning,—however, this is not a necessary practice.

HARVESTING.

Ordinary corn harvesting machinery is quite satisfactory for the harvesting of sunflowers. This crop is fast gaining in importance north of where corn is commonly grown and therefore no corn harvesting machinery is available. At the Chatham Sub-Station this year a two-row sled was devised on 2x4 runners with the front 24 inches wide and widening to 42 inches in the rear. Knives were made from an old crosscut saw and attached to the edges. Two men stood on the sled and gathered the cut stalks in bundles. These were laid at the side of the row where they were collected by wagons and hauled to the cutter about one-half day after cutting. This is an economical way of harvesting where the acreage grown will not warrant the expense of a corn harvester.

ANNUAL HAY CROPS.

The Station has been asked to recommend successful crops for a short season hay crop. A comparative test of crops thought to be suitable, was conducted in 1920 with the following results:—

Crop.	Green forage pounds per plot	Green forage tons per A.	Tons in air dry wt. per acre.
Oats and Vetch	670	12	5.1
Peas and Oats	547	10	3.9
Peas Alone	480	8.6	1.8
Oats Alone	460	8.6	2.
Sudan Grass	370	6.9	1.8
Common Millet	300	5.4	1.3
Hungarian Millet	280	4.9	1.3
Soy Beans	220	3.9	.8

The type of soil and the character of the growing season will be important factors in determining the kind of short season hay crops to use. Dependable results can be expected when the proper combination of these factors are used.

ROOT CROPS.

The work with root crops has been confined to a yield and cost of production with rutabagas in 1919 and a small variety test of roots imported from England in 1920.

Twenty tons per acre were produced in 1919. With the labor conditions as they were that year it cost $3.68 per ton to produce and store in root house ready for winter feeding.

The American purple top rutabaga is the standard variety and the one best adapted to the environment of the Upper Peninsula.

CORN.

The Station has been cooperating with the U. S. Department of Agriculture in testing out four varieties of corn for ensilage. None of the varieties tested have as yet proven to be adapted to the environment of the Chatham Station.

SOYBEANS.

The following varieties of soybeans were tested in 1920: Early Brown, Black Eyebrow, Ito San, and Wisconsin Black. The Early Brown and Wisconsin Black set a few pods, but no ripened seeds were found. The Black Eyebrow and Ito San are later varieties and formed no pods.

FIELD PEAS.

The field pea is quite extensively grown in the Upper Peninsula. A wide variation as to type and variety is found on the various farms. In an effort to determine what particular type is best suited to the section, several varieties are being tested.

The experimental evidence of two years would seem to favor the colored sorts, such as English Grey or Belgian, both as to seed produced per acre and tonnage of forage, though no outstanding variety has as yet been found.

A rate of seeding test in 1920 favors about two bushels per acre for the medium to small size peas and a somewhat heavier rate for the large size peas.

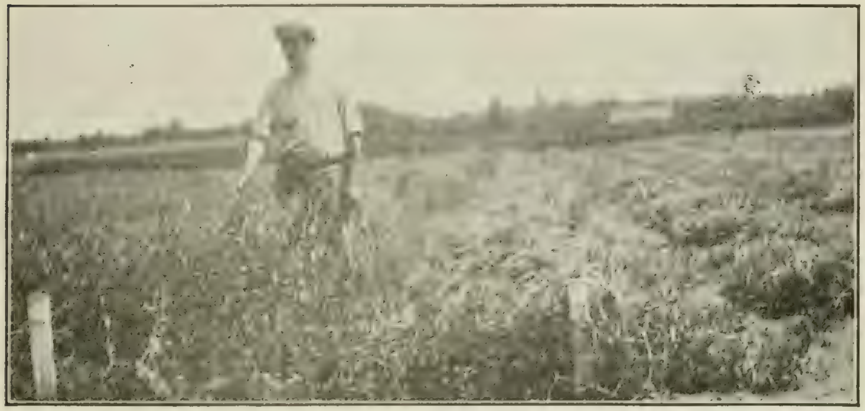

Fig. No. 14. Yields of thirty bushels of shelled peas per acre are not uncommon. This is a source of cheap protein feed for the livestock men of northern Michigan.

Field Results With Silage Crops.

The Station each year grows silage for the winter feeding of the dairy cows and sheep. This permits the careful checking up under field conditions of those crops tested in an experimental way.

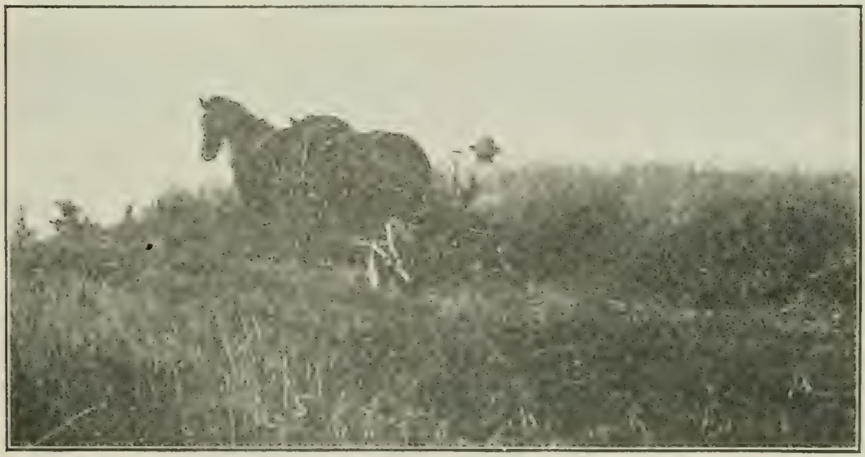

Fig. No. 15. Peas and Oats are a dependable silage crop for northern Michigan.

PEAS AND OATS.

Six acres of sod land was plowed late in the spring of 1919 and planted to peas and oats on May 28th, at the rate of one and one-half bushels of oats and one bushel of peas to the acre. This was very rich land, but owing to late plowing and the long drought, the crop did not make a very good growth.

Twelve acres of peas and oats were planted in the spring of 1920. One and one-half acres yielded 8⅓ tons green forage per acre and was put in the silo. The balance of the field was cut for hay and fed out to sheep.

SUNFLOWERS.

One acre of sunflowers was put in the silo about Sept. 15, 1919. No difficulty was experienced in running the sunflowers through the silo filler. The silo was opened about November 15th, and while about five inches of the top was spoiled, the balance kept in an excellent condition. The cows did not take readily to it on the start, but no more difficulty was experienced than in breaking cattle into other silage. The silage was increased slowly, until the milking cows were getting thirty pounds per day. They gave every indication of wanting more, but owing to the very limited amount of silage, it was not advisable to increase the amount. The cows gave an excellent flow of milk while the sunflowers were being fed, but no direct comparison could be made, owing to having but the one silo.

In 1920, seven and one-half acres of sunflowers were sown on May 29th, using nine and one-fourth pounds of seed per acre. The plants were a little too thick. When they were about six inches high they were thinned to six to eight inches apart. They were cut and put into the silo when about one-third of the plants were in blossom and yielded 24.6 tons per acre. A frost severe enough to kill potato vines did not hurt the sunflowers.

On December 15th, the sunflower silage was finished, and an equal amount of pea and oat silage was given. The cows seemed to object somewhat to the change for the first few feeds, but soon were eating the pea and oat silage apparently as well as they had the sunflower silage.

On careful examination of the daily milk records, before and after the changes of feeding the different silages, no appreciable difference could be found. This short test would indicate that the sunflower silage is as good as pea and oat silage for dairy cows.

For the reasons that farmers of the Upper Peninsula need additional cultivated crops to keep down weeds; that sunflowers produce a greater tonnage than any other silage that can be grown, that it matures quicker than corn; that they can stand considerable frost without serious damage; and, that a succulent feed for winter use is the feed most needed by livestock men, it would seem advisable for farmers to look carefully into the merits of this new crop and give it a trial, under their conditions.

Potato Experiments.*

Experimental potato work has been in progress at the Chatham Station for the past several years. The investigations have included experiments on method of planting, time of planting, cultural methods, seed treatment, seed selection and other economic factors of potato production. The work herein reported has to do with the work of the past two seasons. It is the intention of the Station to include the evidence of the potato experiments conducted, in a general field crops bulletin to be issued in the near future.

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*Mr. J. Wade Weston, Extension Specialist and Mr. J. E. Kotila potato disease specialist cooperating.

CULTURAL TESTS.

Methods of cultivating the potato crop are effected by the type of soil, drainage, presence or absence of noxious weeds and way of planting. The comparisons made were based on the methods in use on farms in this territory. The experiments were conducted on a calcareous sandy loam soil with more than the usual amount of rock present.

Seed Treatment:—Seed potatoes have been handled in four ways to determine the effect on the ensuing crop. (1) Treating with corrosive sublimate; (2) with formaldehyde; (3) leaving the potatoes in the ground over winter and digging them in the spring and then green-sprouting them for seed, using no treatment; (4) planting the ordinary cellar storage potatoes.

With the above methods the most favorable results have been obtained with corrosive sublimate, old style treatment. By this treatment the potato seed piece is freed from the scab and Rhizoctonia (Black Scurf) organisms, thus getting a better start for the young plants. Corrosive sublimate plats out-yielded and gave a better quality of potatoes than the other plats, though Scab and Black Scurf of the potato was prevalent on all plats at digging time. The soils of the Chatham Station are high in lime content and appear to be natural harbors for scab and Rhizoctonia organisms, even on new soils recently brought under cultivation.

Fig. No. 16. Digging potatoes at the Chatham Station in 1920.

Time of Planting—Two varieties, Green Mountain and Rurals were used in this experiment. The earliest planting was made on May 19th and a plat planted every week until June 30th, making seven different dates of planting.

Time of planting potatoes in the Upper Peninsula is influenced by the growing season. Late potatoes planted early in the spring just so as to escape the late spring frosts will have a sufficiently long growing season to develop and mature a crop before the early fall frosts. The character of the average growing season is such that it allows for the continuous development of the potato plant. The plantings made the last two weeks in May gave a maximum crop for both varieties. Plantings up till the 10th of June gave a fair crop and were sufficiently mature to store over winter. Plantings made the last two weeks of June gave small yields and immature potatoes. Fall plowing is a very desirable practice in potato culture in the north, as it allows for proper fitting of the seed bed for early spring planting.

Green-Sprouting vs. Unsprouted:—The experimental evidence indicates that green-sprouting is a very desirable practice when for any reason it is found impossible to plant as early as desired. Green-sprouted potatoes will, when planted on the same date as unsprouted, give a crop that will mature from a week to ten days earlier than unsprouted stock. Spreading the potatoes out in diffused sunlight to sprout also allows the grower to discard any tubers which tend to produce weak sprouts, thus allowing for the selection of only good viable seed stock. It also aids in discovering varietal mixtures.

Cultivating:—The experimental evidence of two years work indicates: The usual method of cultivating deep when plants are small and gradually working to shallow as season advances, is the better one. The harrowing of potatoes before plants are up aids in control of weeds, but does not increase the yield. The flat culture on well drained potato soils increases the yield over hilling providing the seasonal rainfall is not above normal.

Fertilizer Tests:—In 1919 Acid Phosphate was applied broadcast and harrowed in at the rate of 250 and 500 pounds per acre. An apparent gain was noticeable for the first 250 pounds. The fertilizer tests in 1920 were conducted in cooperation with the National Soils Committee. A 3-10-4 ferfilizer was used at varying rates from 500 to 1,500 pounds per acre, applied in the row with a fertilizer attachment to the planter. The fertilizer plats all gave an increase in yield over unfertilized plats, though no benefit was apparent by increasing the rate of application above 500 pounds per acre.

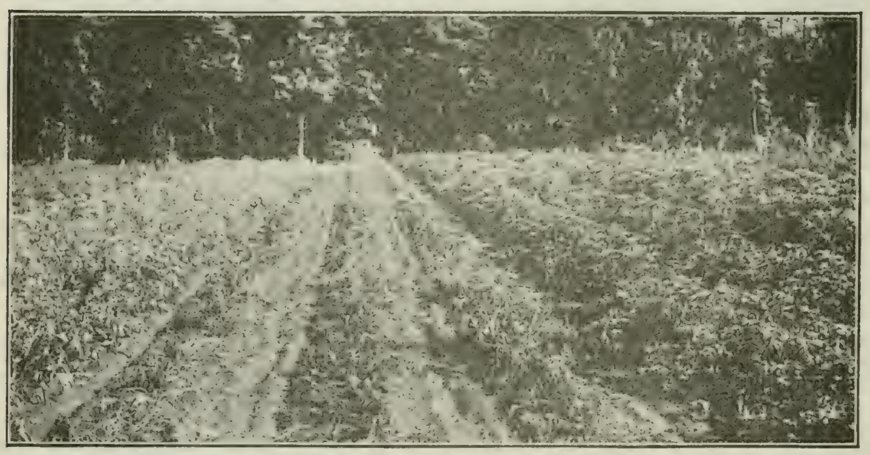

Fig. No. 17. Idaho Rurals (the center three rows) in 1919 were the first to succumb to leaf hopper attack. Russet Burbanks on the left and Rural New Yorkers on the right remained green throughout the season.

VARIETY TESTING.

Several varieties were tested as to their adaptability to produce under the environment of this section. Two important factors influenced potato production in 1919: dry weather and an unprecedented attack of leaf hopper. The leaf hopper seemed to show a preference for certain varieties. The Idaho Rural was one of the first to become seriously infested. This variety was damaged early in the season and ripened prematurely. The season of 1920 was more favorable for potato production, it being a more nearly average season as to rainfall and invasion of insects. The experimental evidence of two years would indicate that of the varieties tested, the Early Ohio and Irish Cobblers have the lead in the early class and the Green Mountain and Rurals in the late class where yield and quality are considered.

SELECTION WORK WITH POTATOES.

The potato selection work began in 1919 with tuber unit selection. About three hundred tubers were selected from seven different varieties, which are fairly well adapted to the Upper Peninsula. Those were planted four hills to the tuber and the product of each tuber kept separate at harvest time. A range in yield was obtained from .75 of a pound in the lowest producing tuber to 9 pounds in the highest. The better tuber progenies from these various varieties were planted in progeny rows in 1920. These progeny rows were carefully studied as to their suitability for increasing. Mr. Weston eliminated any that did not give promise of being characteristic of the variety and Mr. Kotila eliminated any that gave an indication of possessing undesirable disease characteristics. From those progeny rows, that proved to be "breeding true to variety" and that appeared to be free from such diseases as Mosaic, Curly Dwarf, Blackleg, etc., the best one or two progeny from the standpoint of yielding power were selected to be increased in 1921 on new ground isolated from other potato plants. These best progeny increases will be subject to a very careful disease study in order that any disease infected plants may be rogued out and thus allow the harvesting in the fall of high yielding disease free strains. The intention is to isolate a superior yielding, disease-free stock of seed and have it increased under controlled conditions. Such controlled conditions could probably best be realized on an island similar to the Rosen Rye project on the South Manitou Island, (article to be found in November 1920 issue of Experiment Station Quarterly).

POTATO DISEASE INVESTIGATIONS.

Potato disease investigations were first undertaken at the Upper Peninsula Station in the summer of 1919 in co-operation with and under the supervision of specialists at the Michigan Agricultural College in the Botany Section of the Experiment Station. The aim of the work has been to study those potato diseases which are most serious in the Upper Peninsula fields, to determine their causes, and to recommend control measures.

The three main lines of investigation which have been conducted are as follows:

1. Potato Seed Treatment.
2. Investigation of Potato Blackleg.
3. Investigation of Hopperburn.

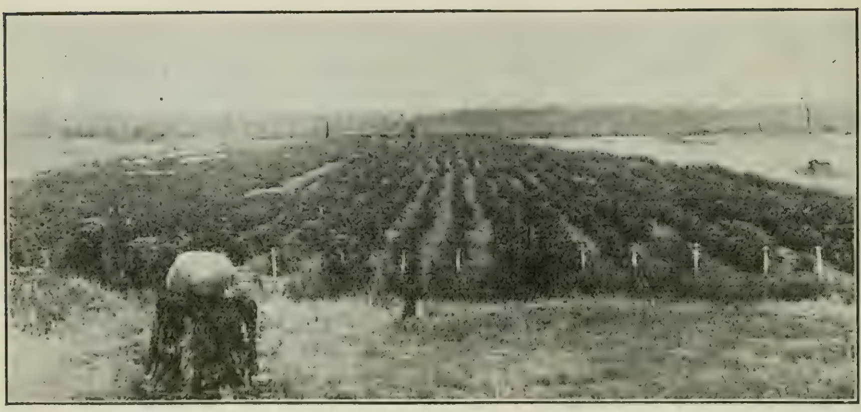

Fig. No. 18. 1919 Seed treatment and disease plats. These plats are planted in half-peck lots which allows for repetition and takes care of differences in results due to soil variation.

SEED TREATMENT.*

The seed treatment experiments carried on during the 1919 and 1920 seasons have been duplicates of those conducted at the College during the same seasons, the seed stock and treatments being identical at both places. In 1919 the treatments were made at East Lansing and half of the seed sent to Chatham for planting. In 1920 the procedure was reversed and all treatments were made at the Upper Peninsula Station and half of the seed sent to the College for planting. Corrosive sublimate, mercuric cyanide, and formaldehyde were used as disinfectants and various lengths of treatment were tried.

RHIZOCTONIA.

Although the experiments at Chatham and East Lansing were identical, the data obtained at the former place during the two seasons have not been comparable in all respects to those obtained at the latter. In all cases much better control of Rhizoctonia (Black Scurf) and Scab was obtained at the College than at the Upper Peninsula Station. Excellent control for Rhizoctonia and Scab was obtained at East Lansing by corrosive sublimate treatment for 30 minutes. Thirty-minute treatment with formaldehyde also controlled Scab but was not effective for Rhizoctonia. While good control for Rhizoctonia was obtained at the Upper Peninsula Station by use of corrosive sublimate with both the 30-minute and hour-and-a-half treatments, the control was not as complete as at the College. The longer treatment (one and one-half hours) gave better results at Chatham in 1920 than the shorter (30 minutes) treatment, whereas in 1919 the 30-minute treatment was just as effective. At the College during both years the short treatment was found to be as effective as the long time treatment.

The corrosive sublimate treatment of potatoes to control Rhizoctonia and Blackleg is recommended as follows:

Select only sound, desirable tubers for treatment. Scabby, bruised, or partially rotted tubers are unsafe.

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*For description of the potato diseases discussed below see Special Bulletin No. 85, "Michigan Potato Diseases."

TREAT SEED IN THE FOLLOWING MANNER.

Soak the seed tubers in corrosive sublimate solution for one-half hour. The solution is made with four ounces of corrosive sublimate in 30 gallons of water. This treatment controls Scab and Black Scurf. Reinfection from untreated sacks must be avoided. Disinfect these containers in the treating solution.

POINTS ON THE TREATMENT.

Corrosive sublimate crystals or the diluted solution are deadly poisonous. Use precaution and keep this material out of the way of live stock or children.

The crystals dissolve slowly in cold water, but rapidly in hot water.

Treated tubers are not safe to feed to stock.

Corrosive sublimate, as the name indicates, attacks metals. It must be used in **wooden** vessels.

Potatoes should be **uncut** when soaked.

Treatment with small lots can be readily given by use of a barrel, soaking one sack at a time.

Larger quantities can most readily be handled in a large vat made of heavy stuff, holding 8 to 12 crates at a time. It is well to make this vat watertight by the use of heavy duck lining, painted with some water-proof paint, such as asphaltum.

The solution can be used four times. It loses strength, due to the potatoes taking out more of the chemical than they do of the water. After the fourth batch is treated, make up fresh.

The addition of one ounce of corrosive sublimate to 30 gallons of solution after each batch is dipped, keeps the treating solution at the proper strength.

Experiments completed since 1917, at the Michigan Agricultural College, show that treatment for one-half hour is as efficient as the longer soaking (1½ to 2 hours), previously advised.

SCAB.

An interesting fact was gleaned from the seed treatment experiments of 1919 and 1920, in relation to Scab control in the limestone regions of the Upper Peninsula. Although corrosive sublimate was found to be effective for Rhizoctonia and Blackleg, neither this disinfectant not formaldehyde were found to control Scab. Plats planted with clean seed which had been treated with corrosive sublimate showed as much Scab as plats planted with scabby seed which had not been treated. These plats were planted on virgin soil of limestone formation, which had never borne a previous crop of potatoes. High percentages of Scab were found in all plats regardless of previous treatment. This would indicate that the Scab organism must be present in the virgin calcareous soils of the Upper Peninsula, and that seed treatment for Scab control is not effective in such areas.

Knowing that the scab organism requires a sweet or alkaline soil for growth and is not present in acid soils, some experiments were conducted in 1920 to change the soil reaction so that it would become more acid or sour, and thus discourage the growth of the Scab organism. Sulphur was used in these trials and was applied at planting time. At harvest the yields from these plats did not show any appreciable decrease in the percentage of Scab, but soil samples taken shortly before harvest showed that the soil reaction had changed sufficiently to prohibit the growth of the Scab germ. It is probable that the change in soil reaction was not brought about quickly enough and that the young tubers had become spotted before the change was brought about. Although control by soil treatment was not obtained during the first season's experimentation, the results have not been entirely discouraging and the 1921 trials will be planned to remedy the defects of those of the past season. The solution of the Scab problem will be of great value to the potato growers in the limestone areas who at present can grow but one crop of marketable potatoes on a given piece of land and must each year select a piece of virgin soil for their potato fields.

BLACKLEG.

This disease is one of the most important potato troubles in the Upper Peninsula. It is very widespread and during cold, wet seasons, which are particularly favorable for the disease, the loss incurred through death of hills in the field and rotting of tubers in storage runs high. Losses of from 25 percent to 75 percent of the crop are not uncommon, and in seasons of comparative drought fields showing as high as 10 percent of Blackleg can often be found.

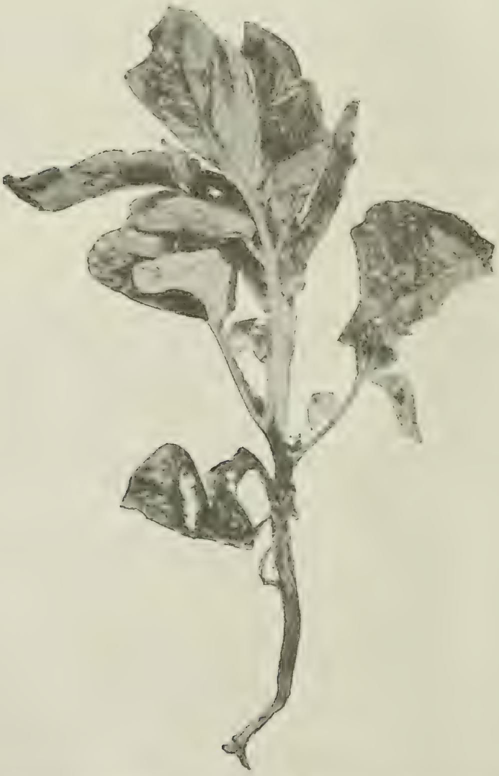

Fig. No. 19. Young potato plant affected with blackleg, showing characteristic blackening of stem. This disease can also be recognized by the yellowing and wilting of the leaves.

The investigations conducted upon this disease have shown that the trouble in the Upper Peninsula is caused by a bacterial organism which is carried from year to year in diseased tubers. The trouble is spread for the most part in storage bins where diseased tubers rot and infect the neighboring tubers. When such tubers are planted high percentages of Blackleg in the field is the result. It has also been found that the disease will winter over in diseased tubers which are left in the ground. Potatoes should not, therefore, follow potatoes in rotation and at least four years should intervene between crops.

Blackleg of potatoes can very easily be controlled by treating the seed tubers with corrosive sublimate, as described for Rhizoctonia, and by rogueing out diseased hills during the growing season. It is important that the rogueing be severe and that the entire hill, showing the disease, be dug up. Quite often hills will be found in which only one or two stems show the characteristic blackening while the others are apparently healthy. Should these be left in the field they too will later go down with the disease and produce tubers which will spread the disease during the storage season.

HOPPERBURN (TIPBURN).

Tipburn of potato leaves has been known for a long time and until recently was thought to be due to weather conditions. It was noted that during dry seasons the trouble was always severe and it was thought that the burning of the tips and margins of the leaves was due to sun effects. In 1918 Dr. E. D. Ball of Wisconsin, demonstrated that a leaf hopper (Empoasca mali LeB.) was the cause of the trouble. Dr. Ball's discovery, however, was so revolutionary that plant pathologists and entomologists alike were rather hesitant in accepting it as a fact. It was to confirm or contradict Dr. Ball's work that the Hopperburn investigations were undertaken. By means of cage experiments in 1919 it was conclusively demonstrated that leaf hoppers were the cause of the burning of the tips and margins of potato leaves. Results of these experiments were reported in Phytopathology 10: 61-62, 1920.

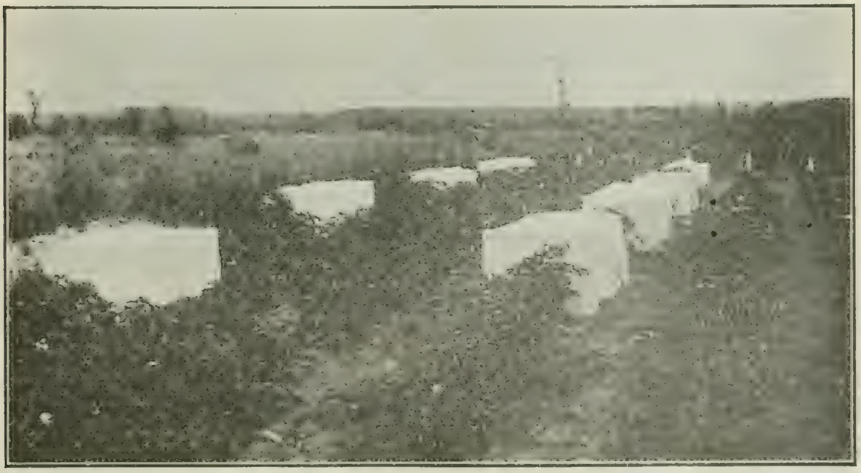

Fig. No. 20. Cages used in leaf hopper experiments. Hopperburn was produced in cages into which leaf hoppers were introduced. No burning resulted in the cages which were kept free from all insects nor in those cages into which plant lice were placed.

The importance of this trouble in the Upper Peninsula was revealed during a survey which was made during the latter part of July 1919. Potato fields in six different counties were visited and in five of these Hopperburn had caused serious loss. Many fields were visited which were a total loss, the tops being killed before the tubers had reached marketable size. The loss from this cause in 1919 was estimated by J. W. Weston, Assistant County Agent Leader, as $1,000,000. Hopperburn was found to be more serious on light than on the heavier soils, early varieties were more susceptible than later maturing varieties. Observations made on the variety plots at the Station confirmed the findings of the survey. Of the early varieties Bliss Triumph was found to be the most susceptible and was followed in order by Early Ohio and Irish Cobbler. Of the late varieties the Idaho Rurals were most susceptible and were followed in order by Green Mountain, Russet Burbank, and Rurals. The last two varieties remained green throughout the entire season although the foliage was curled upward.

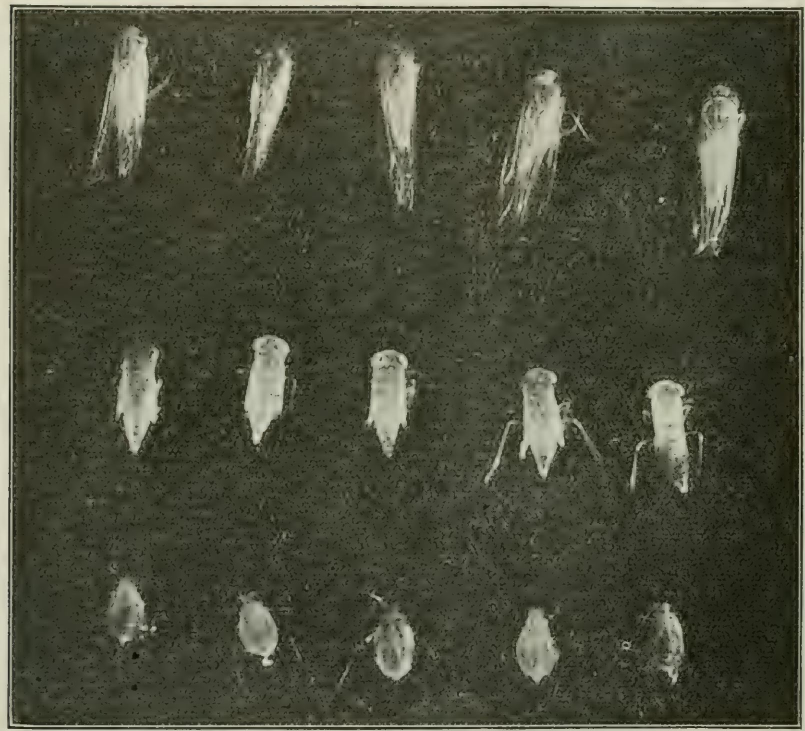

Fig. No. 21. Potato leaf hopper adults (top row), leaf hopper nymphs (middle row), plant lice, aphids (bottom row). The leaf hoppers, especially the nymphs, cause the burning of the leaves. No burning results from the attack of plant lice.

The importance of the leaf hopper (Empoasca mali LeB) as a potato pest having been determined, the 1920 investigations comprised life history studies and control measures. The former revealed that the Potato Leaf Hopper passes the winter in the adult stage, and in the spring after hibernation feeds on various field crops and weeds until the early potatoes break through the ground. At this time the adults fly to the potato fields and the females lay great numbers of eggs on the young potato vines. Thousands of eggs are known to have been laid on a single hill. If weather conditions are favorable—dry and warm—these eggs will hatch in approximately fifteen days. A longer period will be required if the weather is cold. The growing nymphs are voracious feeders and by sucking from the veins and veinlets near the edges of the leaflets cause the characteristic burning of the leaves. Very little burning is apparent before the nymphs begin to appear, the adults causing a very small percentage of the injury. A period of fifteen days of favorable weather conditions are required for the nymphs to reach maturity. Approximately a month or thirty-five days is estimated as the length of time required for a leaf hopper egg to hatch and the nymph to reach the adult stage and lay eggs for the next generation. It is probable therefore that in favorable seasons there are two generations of the potato leaf hopper under Upper Peninsula conditions, the first generations reaching the adult stage during the latter part of July and the second generation the last of August and first of September. Nymphs of the third generation are no doubt killed by frosts before reaching maturity.

BORDEAUX MIXTURE AIDS IN CONTROLLING HOPPERBURN.

Ever since bordeaux mixture* began to be used as a spray for potatoes it has been repeatedly noted that the percentage of Tipburn in sprayed fields was considerably less than in fields which had not been sprayed. The fact

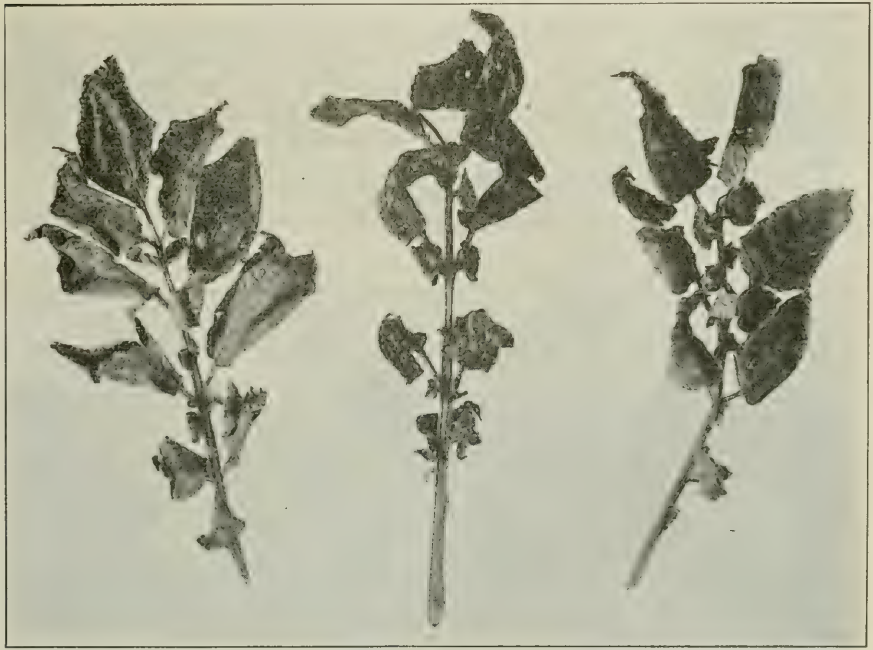

Fig. No. 22. Potato leaves showing burned areas (Hopperburn) at tips and margins caused by potato leaf hoppers.

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*Directions relating to the manufacture and use of bordeaux mixture may be obtained from your County Agricultural Agent or by writing the Michigan Experiment Station, East Lansing, Mich., for Special Bulletin No. 85—Michigan Potato Diseases.

that Hopperburn, if not identical to, at least resembles Tipburn very closely, led to the presumption that bordeaux mixture might be a factor in the control of that trouble also. The potato plats at the Station were sprayed weekly with 5-5-50 bordeaux mixture, five applications being made during the growing season. The sprayed and unsprayed plots were kept under careful observation throughout the season and at no time were leaf hoppers as numerous in the sprayed as in the unsprayed plots. On September 5th hill counts made for Hopperburn showed 1.71 percent in the sprayed versus 27.75 percent in the unsprayed plats. **Bordeaux mixture was instrumental therefore in the control of Hopperburn.** The spray does not kill the leaf hopper but merely acts as a repellant. Vines covered with bordeaux mixture are not relished by the insect and it flies away to other hosts or other potato fields which are not sprayed. For best results the first application of bordeaux should be when the vines are 5 or 6 inches tall, followed by a second spraying about a week later. At least two subsequent applications should be made at intervals of 10 to 14 days. Getting the vines covered with bordeaux mixture early will ward off the overwintering adults and at the same time insure freedom from the ravages of the first generation nymphs. The subsequent sprayings will repell the adults of the first generation which come back about a month later to lay eggs for the second generation. This results in the losses from Hopperburn being reduced to a minimum.

MISCELLANEOUS PROJECTS.

There are many problems connected with the developing of a ''new agricultural territory,'' such as the Upper Peninsula, that may or may not be of general interest, yet demand attention for those who are interested. Land clearing, muck soil management, sandy soil management, and other similar problems are among those here reported to which the Station is giving attention.

Many of these projects are co-operative where two or more interested parties or organizations are assisting the Station in the solving of the problems to the common good of all.

Fig. No. 23. County cooperative barley and oat test, Delta County 1920.

COUNTY CO-OPERATIVE CROP TESTS.

The various types of soil together with the influence of temperature and moisture on the growing season, effect the farm practices even within short distances. In order that the Station can check up on just what the influence of these local environmental factors are, tests are being conducted in several of the counties. These tests are put on in co-operation with the County Agent. In 1920 four county tests were put on with oats, four with barley, and three with alfalfa.

CO-OPERATIVE CROP WORK ON MUCK SOIL.

The Station is co-operating with J. A. Jeffery, Land Commissioner for the Duluth South Shore and Atlantic Railroad Company in making a fertilizer and grass seeding test on the muck soils of the Seney Swamp area in Schoolcraft county. The fertilizer test was planned by Mr. Jeffery to demonstrate the benefits, if any, that might be derived from the use of various commercial fertilizers and soil amendments on the muck soils of this area.

This work is being conducted on the farm of Mr. H. E. Bullock, five miles west of Seney. Mr. Bullock's co-operation in furnishing the land, material and labor for these experiments is making it possible for the work to be continued in the future. It was unfortunate that in 1919 the particular part of the farm on which the experiments were being conducted, lay in the path of one of the largest swamp fires ever recorded in that section. The crops themselves were not only burned up, but the soil burned to a depth of six to eight inches. The original experiment as put out in 1919 was again put out in 1920 and quite satisfactory results obtained. Work was also started with such crops as mint, cauliflower, cabbages, potatoes, celery and head lettuce. Experiments to determine how best to establish a new seeding on the burned over area were tried. A mixture of several grasses and legumes was seeded under four different sets of conditions; seeding with no cultural work; seeding and harrowing; harrowing and seeding; harrowing seeding and harrowing. Observations of at least one more season will be necessary before drawing conclusions as to how best to seed on this area.

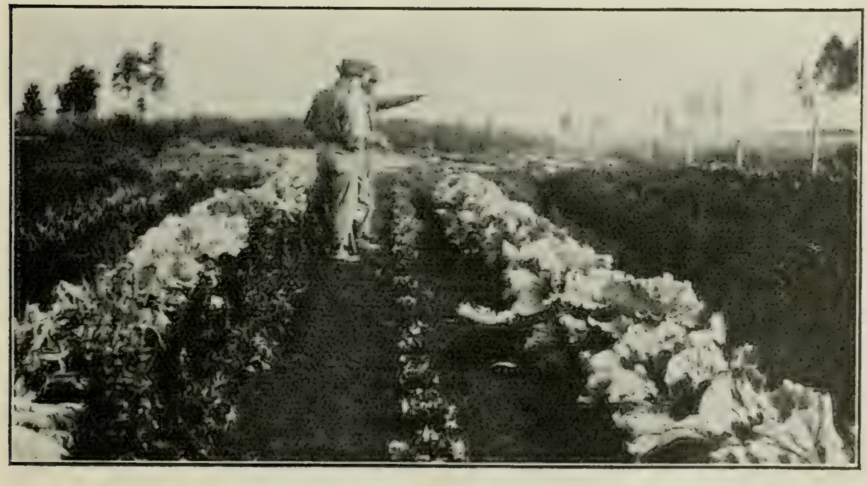


Fig. No. 24. Co-operative "Truck Crop" experiments on the Seney area 1920.

Land Clearing.

The high price and scarcity of labor during the past two years has made it necessary to slow up on the land clearing program as previously planned.

On a tract that was grown up to brush quite heavily a band of sheep were pastured during grazing season of 1918, and were kept on this tract as long as they could get enough to eat to keep them from falling away seriously. The sheep kept the leaves trimmed on all the brush they could reach, also browsed in the smaller brush to such an extent that the tract appeared very open in the fall.

In the spring of 1919, another bunch of sheep were turned in and held there until the latter part of July, when the grazing was practically gone. Our reason for this was to use the sheep as land clearers, to keep any of the smaller brush that remained green, from starting to grow. During the dry weather about the middle of August, slashings of the larger brush was begun, and the sheep were allowed to consume the leaves. The plan being to cut all the larger brush at this time, with the belief that it would not start to grow from the roots. After working two days at this, with one man, a fire broke out and swept the greater part of the area, besides a much larger tract, before it could be controlled. The fire had the desired effect of killing the brush and burning the larger number of stumps and logs. About the middle of November a part of this burned area was seeded to red clover, alsike clover and timothy, the balance of which was seeded early in the spring. The object of sowing the seed at this time was that it would get worked down into the soil during the winter and early spring before the weather would warm enough to germinate the seed. At the same time, the germination of the seed would not be weakened, owing to the heavy snows during the winter.

This tract was left without pasturing until about the middle of the summer, when light grazing was permitted in order to destroy the weeds and small brush that might get started.

Another ten acre tract, between the railroad and the barns was partially stumped; over one-half of the stumps being pulled with the team, a few others pulled with a one man stump pulling machine, during a demonstration conducted on ''Field Day,'' August 14th, and a few blown out with dynamite, on the same day, during a demonstration conducted by a powder company.

The field is now being used as a pasture for the dairy herd, but it is the plan to develop it into a cultivated field in the near future.

Forty acres lying east of the cleared land on the upper farm were staked off and plans made to clear it. Twenty acres were cleared and plowed in time to put in crops of barley and oats and peas. The other twenty acres are partially cleared and will be completed in time to put in crops next year.

The system used was to (1), pull all stumps and brush with a team that could be pulled leaving them where they could be readily piled. (2), Blow out the remaining stumps with low grade powder. (3), Pile and burn the logs, stumps and the small sticks and chunks that lay a short distance from the piles. (4), Using team with wagon or stone boat, give the field a careful pick-up of sticks, chunks and fire brands, making piles of the same in straight rows across the field the way it will be planned. Burn the piles when dry. (5), Plow and scrape the large knolls into the holes. (6), Plow the field, leaving a strip where the rows of chunk piles are until such time as they are dry enough to burn. (7), Pick up stone and chunks plowed out. (8), Use spring tooth harrow, disk harrow, and leveler until land is in shape to seed.

It is the plan of the Station to push the land clearing as rapidly as possible, until there is enough land under cultivation to supply sufficient feed to enable an increase to be made in the flock of sheep, the dairy herd, and also to feed a beef herd, without having to buy any roughage.

FENCING.

One and one-fourth miles of 48 inch woven wire fence was erected this season, which enclosed another tract of land that will be used for grazing, with the exception of forty acres now being cleared. The wire was purchased at 63 cents per rod. The posts were cut on the Station farm.

Two miles of fence will be erected in the spring which will finish enclosing the Experiment Station property. This will give another half section for grazing. A large part of this will make good cultivated land as soon as it can be cleared. All of this land has been seeded, but owing to adverse conditions at the time of seeding, the land has not sodded over completely.

Cut-Over Land Management.

The following is given very largely for the purpose of offering suggestions to the new settlers in Northern Michigan.

In observations taken while traveling over the Upper Peninsula, it has been found that a great variety of methods are used in clearing brush land, and from these, conclusions are drawn that will furnish items for consideration, at least.

It is self-evident to any one that the green brush must be destroyed. In accomplishing this it is found that sheep and goats work to very good advantage. To get the best use from them, the land should be fenced in small enough areas to compel the number of sheep or goats to do thorough work in trimming the brush as high as they can reach. Then the balance of the brush should be slashed, and as soon as convenient and the weather and winds are right so that it will be safe to burn, fire can be used to excellent advantage to sweep over the area, cleaning up the brush, and many of the logs and old stumps.

In using fire to the best advantage, one should be careful to have a wide border burned around the area to be cleared, before it becomes too dry, thus preventing danger of the fire destroying adjoining property.

As soon as the fire has entirely died out, grass seed should be sown. The kinds of grass seed will depend largely upon the types of soil. For well drained soils, the following mixture has been a success on the Experiment Station tract.

Alfalfa	2 pounds
Mammoth Clover	2 pounds
June Clover	2 pounds
Alsike	2 pounds
Timothy	4 pounds

If the ground has been allowed to settle thoroughly after the burning then it would be advisable to wait until late fall or early spring for seeding. A light snow will be found a great advantage while sowing, as a person will be able to do the work without the use of stakes or the possibility of double seeding, or of missing large strips, as he will be able to keep an approximate distance from his back tracks.

This new seeding should not be grazed until the plants become well rooted, and then not severely enough to prevent many of the plants from re-seeding. It should be kept for grazing until such a time as the brush roots have disappeared, and the stumps are partially decayed. Only in exceptional cases has it been found advisable to break land where the green brush has recently been removed. There are cases however, where a new settler has no other alternative than to break up a small area of green brush land, when getting started, and in many cases has not the means to fence, or to buy sheep or goats for clearing the brush. In that case it is usually the custom to use an axe or a brush hook for cutting the brush, removing the small stumps with the aid of a horse power or a power puller, and plowing around the larger stumps until they have partially decayed.

In removing the stumps, three factors work to good advantage. First remove all stumps that it is possible to, with a team, and the balance can be removed with dynamite or power stump pullers. Whether to use dynamite or a stump puller will depend on the condition of the stump and the condition the soil is in. If the body of the stump is quite rotten a puller will shear off the top leaving the roots in the ground, but where the tops are solid and the stumps fairly thick, the puller will work to good advantage. One thing in favor of dynamite is that it loosens the dirt from the roots, while the power pulled stumps require more or less hand labor in removing the dirt.

There are several types of stump pullers on the market. One that can be worked with one man, working a lever, and others with one or two horses. The type to be selected will depend largely upon the amount of work to be done and the amount of money the settler can afford to put into equipment of this kind.

The amount of dynamite to be used varies greatly with different kinds of soil. The relative cost of dynamite and hand labor will make a difference in the amount of power to be used. By this is meant, whether it will be advisable to put in sufficient charge to blow the stump entirely out, or whether a smaller amount can be more economically used, by simply splitting the stump and pulling the parts out with a team.

In many cases farmers find it advisable to leave some of the larger, greener stumps, working around them for two or three years before blowing them out. This also will depend upon the amount of money the farmer is in position to expend in clearing the land.

Where the power pullers are used extensively, it will be found very economical to use the stump piling rig, in order to get the stumps in large piles, so that they will dry out and burn to better advantage, but where the dynamite is used the stumps are usually broken up so that they can be handled by hand.

FARM MANAGEMENT FOR THE NEW SETTLER.

Too much emphasis can not be placed on the importance of the new settler making plans for the location of his buildings and the size and shape of his fields, as he hopes to have them when his farm is under cultivation.

Too many sets of buildings are constructed in a haphazard sort of way because no plans have been made, thereby compelling the farmer to work at a disadvantage all of his life, for it is seldom that buildings are moved after they are once built, unless they are torn down, and replaced by larger ones.

Long fields always work to better advantage than square ones. Too many farmers have a lot of small fields rather than a few large ones. This makes the cost of production greater, while it also makes it more inconvenient for the farmer.

In portions of the State where it is not advisable to grow corn, the newly broken land is usually put into potatoes, rutabagas, oats, or oats and peas. Barley, wheat, or rye do not adapt themselves as readily to first breaking as do potatoes, oats, rutabagas, or oats and peas.

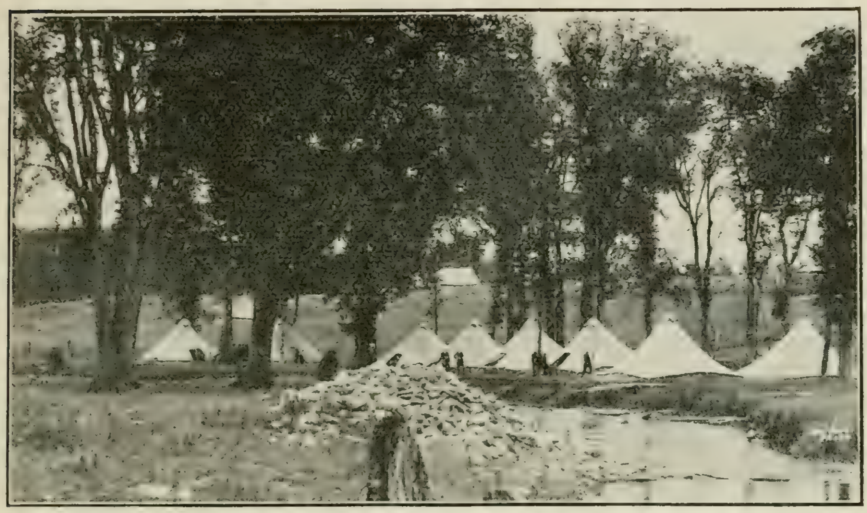


Fig. No. 26. Boys' and Girls' Club camp, August 14-16, 1920.

The settler who starts with a few head of high grade livestock **and continues to breed them to pure bred sires,** and increases his numbers as rapidly as it is possible for him to raise the winter feed, is much surer of success, than the farmer who is indifferent about the blood lines of his stock.

The kinds of stock to raise depend largely upon the likes and dislikes of the individual owner, the type of soil, the amount of grazing land, the breed that is most popular in the community, and the distance from the market. The farmers adjacent to a railroad, creamery, or cheese factory find it to their advantage to go into the dairy business, with hogs and sheep as a side line, raising principally stock feeds, with possibly potatoes for a cash crop. On this type of farm a silo is usually a good investment.

The farmer farther back from a railroad or market center will find it to his advantage to raise sheep and beef cattle, in preference to specializing in the dairy business, as land is usually cheaper in these localities. This makes cheaper grazing. The farmer should, however, plan on producing at least one cash crop. That crop should be the one best suited to the conditions, which probably would be potatoes, peas, wheat, rye, or clover seed. The principal work would be raising large quantities of clover, barley, oats, silage crops, and rutabagas, the varieties of these crops depending somewhat upon the soil conditions.

Annual Farmers' Round-Up.

In the summer of 1919, it was felt that a closer contact should be made between the farmers of the Upper Peninsula, the Experiment Station and the work of the Extension Department of the Michigan Agricultural College. As a means of gaining this, a Farmers' Round-Up was put on August 13th and 14th, the program consisting of a County Agents', Boys and Girls Club Leaders' and Home Demonstration Agents' Conferences, a meeting of the State Board of Agriculture, livestock and farm crops demonstrations, and a speaking program with one speaker representing each phase of the development of agriculture in the Upper Peninsula.

At this meeting a unanimous vote was passed requesting an annual event of a similar nature to be held at the Station. About six hundred people were present at this meeting.

In 1920, a much more extensive program was planned with practically the same departments co-operating. As an addition, the Summer Boys' and Girls' Camp for club members was furnished and livestock prizes given for winners of the sheep, hog and cattle judging contests.

Alger county realizing the handicap the Station was working under in providing accommodations for a large crowd very generously volunteered to entertain the guests to a barbecue dinner, nearly three thousand people attended this round-up.

STUDIES IN CITY MILK DISTRIBUTION.

BY S. J. BROWNELL.

Special Bulletin No. 111.

INTRODUCTION.

The drift of people toward our cities and the resulting rapid increase of urban populations have given an unusual prominence to all forces affecting a city's food supply and distribution.

During the hearings of the Detroit Milk Commission the writer of this bulletin was impressed with the lack of authentic data concerning some of the many important steps in milk distribution (Special Bulletin No. 99 of this Station). The feature most discussed was that of milk delivery. Some voiced the opinion that milk should be dispensed from cash and carry stations only. Most consumers, however, preferred to have milk delivered at the door in the usual way, but contended that there was waste motion and unnecessary expense entailed by reason of duplication of milk routes. Some testified that they had seen two, three, five and even more milk delivery wagons on the same street. Most city residents were of the opinion that the presence of these wagons on the single street added much to the cost of milk delivery. Some even asserted that its elimination would enable distributors to make a very substantial reduction in milk prices.

While many popular magazine and newspaper articles had been written upon the subject, it was found that little actual study had been made. It was, therefore, in an attempt to ascertain the simple facts in actual practice that the work described in this bulletin was undertaken.

CITIES STUDIED.

The first study was made in East Lansing, Michigan. The College city was selected because of the convenience and opportunity it offered for developing working forms upon which to make further studies, and get acquainted with some of the problems to be met in the larger fields. After East Lansing was completed, Lansing, Kalamazoo, and Flint were studied in the order named.

Lansing is a city of 57,327 people, fair roads, and well laid out for the distribution of milk. It has a city food and milk ordinance enforced by a qualified city food and milk inspector.

The milk supply of the city is handled by 14 distributors operating 31 vehicles of which five are wholesale and 26 are retail. This requires the use of 33 men, 33 horses, seven trucks and 24 wagons. It requires 6,300 quarts of wholesale milk and 6,473 quarts of retail milk to supply the city daily. All milk is delivered in the day time. The wholesale men and part of the retail men make one trip a day, while some of the retail men make two trips a day over the same territory. The wholesale dealers get cash and are paid for lost bottles. The retail dealers use a cash and ticket system.

Kalamazoo is a city of 48,487 people, good roads, although quite hilly on the outskirts of the city. The city is not so well adapted to the delivery of milk as is Lansing, but is fairly well laid out. The city milk and food supply is under the supervision of a milk and food inspector, but there is no workable city ordinance enforced. The milk supply of the city is handled by 18 distributors operating 40 vehicles of which three are strictly wholesale, seven entirely retail and 30 which carry both wholesale and retail. Forty-one men, 42 horses, and two trucks are used to distribute 6,555 quarts of wholesale milk and 6,926 quarts of retail milk to supply the city daily. Wholesale milk is delivered in the day time and two deliveries a day are made to each stop. The milk is sold for cash and lost bottles are paid for. Retail milk is delivered after twelve o'clock at night with one delivery a day and a credit system of monthly collection is used.

Flint distributors were supplying 100,000 people at the time the study was made. Flint is well laid out for the distribution of milk, but with roads in a very poor condition causing detours and smaller loads or more horsepower. It has a city milk and food inspector and a city milk and food ordinance that is enforced. The milk supply of the city is handled by 13 dealers operating 63 vehicles, 18 of which are exclusively wholesale, five entirely retail and 40 handle both wholesale and retail. Besides this there are four wagons which handle only buttermilk and have no regular route, therefore, they are not included in the study. Sixty-six men, 61 horses, 15 trucks and 48 wagons are used to distribute 18,400 quarts of wholesale milk and 11,110 quarts of retail milk to supply the city. The wholesale milk is delivered in the day time with but one delivery a day and is sold for cash. The drivers are allowed to give credit only at their own risk. An effort is made to obtain all empty bottles, but no charge is made for losses. Retail milk delivery is made after twelve at night, all loads are thus delivered before twelve noon. No afternoon delivery on regular routes is made. All milk is sold for tickets or cash, but drivers are allowed to give customers credit at their own risk.

How the Study Was Made.

One complete trip was made with each wagon in the different cities studied, making notes on all the individual problems of each wagon, writing up the route traveled and stops made, size of load, time of delivery, amount sold, number of sales, etc. Enough time was spent with each driver to obtain complete information of his work. The route, every stop, and customer of that driver was then drawn on a map of the city in color so that the deliveryman could be followed in his day's work. Measurements were made to determine the number of miles traveled, both wholesale and retail, the miles of duplication of self, and miles of duplication of others. When all the routes in the city had been mapped one could determine for any place in the city who delivered at each house, how many drivers traveled any street, how many drivers delivered in each block, etc. Because of changing population during the time necessary to make the studies some slight errors naturally have entered, but the average results are not appreciably affected thereby.

To illustrate some of the conditions met with, and to show how data were determined, a map of Kalamazoo was prepared and may be obtained by addressing this Station.

Observation of this map shows that the plan of the city does not lend itself to the most convenient system of distribution, due to a complicated system of streets laid out to furnish personal or community conveniences. Such conditions are an actual hinderance to efficient milk distribution. Kalamazoo, like most Michigan cities, was located on a river because of the many benefits that could be obtained from such a location. The efficient distribution of milk is one of the city's industries which is handicapped as a result of the city plan and location. This is because of the division resulting from the city having been built on both sides of the river, causing extra driving. This driving is also increased through lack of bridges. Flood lands along the river, usually uninhabitable, also increase the waste distance traveled.

The same is true with railroads as with rivers, causing detours and extra traveling in which no deliveries can be made. Centrally located manufacturing plants, various industries, schools, blind alleys and streets, etc., all increase the miles traveled and the unavoidable duplication of routes. Even by taking a portion of any city laid out in regular rectangular blocks (Figure No. 1) and traveling every street as shown in the accompanying figure one will find that if all the streets are covered it will be necessary to duplicate on some of them. There will also be further duplication necessary if another route must pass through this territory to distribute to a farther field.

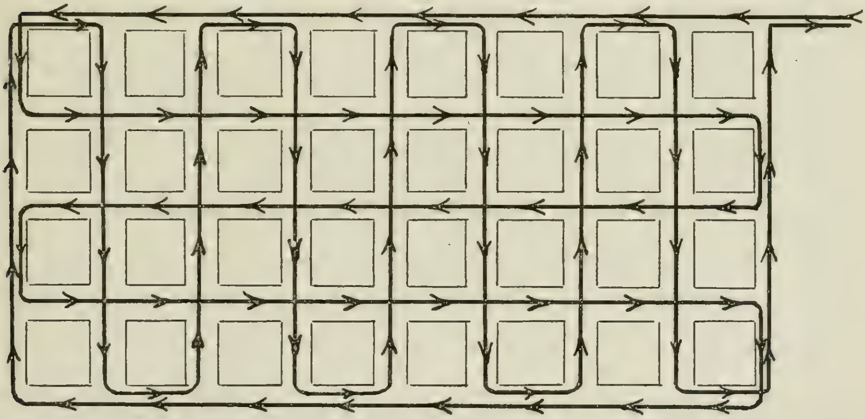


Figure No. 1. Shows a portion of a city laid out in rectangular blocks and the necessary duplication if all the streets are traversed.

Methods of Measuring Duplication.

Several methods have been used by other investigators in determining duplication, all of which may be classed as survey methods. The one used the most, being that which ascertains the number of wagons passing a given place every day. This is also the method used by the consumer upon which to base his conclusions, taking his observations from the front of his house. Several cities have also applied this method by having policemen count the wagons in different sections of the city and making house to house inquiries in different blocks of the city. Thus they find out how many dealers deliver in certain blocks.

Measuring of the miles traveled by all milk delivery vehicles in the city and comparing this to the number of miles of city streets has also been used to determine excess delivery and duplication.

Our method of determining duplication, as previously described in this bulletin (page 361), eliminates the greatest fault of the other methods in that it shows more accurately the necessary duplication in theoretical distribution as for determining duplication in actual distribution.

After the study of milk delivery in each city was completed and while a knowledge of the demands for service in the different sections of the city was still fresh in mind, the city was mapped with a theoretical system of milk wagons designed to supply the entire city from one common starting point. The mileage traveled, and necessary duplication in this system, was scaled from the map, using the city studied as the geometrical figure.

The writer does not maintain that the theoretical system would in actual practice effect all the economies designated in this bulletin. First, because experienced persons have difficulty in laying out a new system and have it work successfully. As soon as actual operations begin omissions and complications are sure to be discovered. Second, a central distributing plant does not have the tendency to give service to the consumer or demand efficiency from its men as is necessary in independent competing companies whose existence depends on efficiency and service.

DUPLICATION OF DELIVERY.

In making a study of the duplication of routes, duplication over the entire route was considered rather than at any given point, and the result is expressed in miles. Total duplication was divided into two classes. First, duplication of others, and second, duplication of self. For example: When in a day's work a wagon for the first time passed over a street which had been traveled on by a wagon previously studied, this was called duplication of others. If any wagon returned over any street which it had previously traveled that day it was duplication of self. The total miles traveled minus the total duplication would give the number of miles of city street covered.

The streets upon which the most duplication is made are those traveled by wholesale wagons. Usually these are the paved streets and a driver will go several blocks out of his way to travel these streets rather than haul a heavy load for a distance on a street in poor condition. There is also more duplication in wholesale deliveries than in retail deliveries. Besides the other reasons that govern duplication of retail delivery there exists the demand from the different classes of business that require deliveries at different times of the day. Places where meals are served and some bakeries require a before daylight delivery. Another trip to the same territory is required to serve the retail stores which open later. Where competition is keen another delivery is sometimes made to the same places, usually right after noon, to supply milk bottled that morning in order to get fresh milk on the market as soon after bottling as possible.

Retail wagons that carry wholesale milk usually deliver their retail loads before seven o'clock in the morning, then double back to supply the wholesale trade in their territory, and collect for cases of milk left at the door before stores were open.

SIZE OF LOAD.

One of the first questions which presented itself in regard to delivery of milk was the size of a load and what constituted a day's work for man and horse.

This resolved itself into the fact that the size of the load was limited to what is a day's work for horse and man. Some of the things found to determine a day's work for horse and man were as follows: Industriousness and efficiency of the man, equipment provided, character of roads, density of population in region covered, season of year, distance traveled, and milk sold per stop. Industriousness and efficiency of the deliveryman at times doubled the load over what a previous driver carried. This was overcome to some extent by paying a minimum wage plus a percentage on sales. Practically all two horse wagons, trucks, and the larger one horse wagons will carry enough milk in bottles on one load to give a deliveryman a good day's work if he delivers the whole load to retail customers and does his work well. The efficiency of the man in handling his own route has more to do with the efficiency of delivery than any modification in the handling of collective routes. Much time can be lost and sales affected by poor management of the driver. One minute spent at each house stop in summoning delinquent customers or in conversation or making change with each customer means over four hours time a day outside of delivery. The art of house to house salesmanship is possessed by few and to accomplish these transactions in the minimum time without offense to the buyer is an even more rare ability. Unnecessary duplication and drives and many other smaller items make the salesman the big factor in efficiency of delivery.

The equipment provided the man may increase or decrease his delivery. A sturdy wagon of suitable size, supplied with plenty of reliable horsepower, facilitates delivery. On good roads more can usually be accomplished with one horse than a team, because generally one horse will learn the route, follow the driver and respond to his commands better than will a team. Some teams, however, are very satisfactory and in some cases a necessity on routes where the roads are bad or where large loads are carried. Wagons so small or weak that extra trips must be made for more milk or have milk delivered to them at field points will retard deliveries. Poorly constructed wagons which demand extra labor and shifting of cases, and poor delapidated wagons typical of the cheap huckster class, will delay the service of delivery. In order to obtain the best results the wagon should be large enough to take care of any temporary expansion of business, and the largest day's delivery of the year. This may cause the deliveryman to work overtime a small portion of the year. A one-man milk route is never large enough to support two routes even during the rush season.

Roads affect the size of load and rate of delivery. Their condition varies at different seasons of the year. Rough as well as heavy roads demand slow driving; and when the roads are real bad, as in the spring, the load must be greatly reduced or an extra horse added. This is true mostly for the routes covering the outskirts and newer portions of a city. Those more centrally located usually have the better roads the year around.

The distance traveled affects the size of the load by limiting the time to carry the milk from the wagon to the door step. This is true only where mileage is excessive as the driver usually takes advantage of short drives to shift cases, fill carriers, mark charges in his route-book or take tickets from the bottles.

Summer season makes a larger demand on milk distribution than any other season. For this reason the wagon must be able to take care of its maximum load in the summer, while during the other seasons the load decreases. Data presented in Table I show that there is a 23 per cent increase in city sales during the spring and summer months over the low period of the year.

Lenten season, epidemics, and holidays also tend to increase the loads. A brief water epidemic in one city increased the sale of milk 25 per cent for the whole city in a week's time.

TABLE NO. I

THIS TABLE SHOWS THE DIFFERENCE IN THE AMOUNT OF MILK SOLD IN WINTER AND SUMMER.

Dealer Number	March	July	Difference	Per cent Gain	Per cent Loss
1	7,196.0	9,752	2,556.0	35.52	....
2	280.0	276	−4.0	....	1.42
3	206.5	174	−32.5	....	15.74
4	230.0	231	1.0	0.4347	....
5	1,513.0	1,694	181.0	11.96	....
6	638.0	830	192.0	30.09	....
7	223.5	*	−223.5	....	100.00
8	266.5	228	−38.5	....	14.45
9	401.0	804	403.0	100.49	....
10	282.0	204	−78.0	....	27.62
11	347.5	400	52.5	15.11	....
12	508.0	400	−108.0	....	21.26
13	413.0	454	41.0	9.94	....
14	268.0	298	30.0	11.19	....
Total	12,773.0	15,745	2,972	23.27	....

*Out of business.

UNNECESSARY DUPLICATION.

Upon comparing the actual delivery with the theoretical we find that there is a great difference in the amount of duplication. Some things which affect this have already been mentioned on pages 5 and 6. From the theoretical system we find that it is impossible to formulate a system of delivery in which the entire city is served without some duplication. The duplication which is unavoidable we have considered as necessary duplication. The difference in amount of duplication between the actual and theoretical systems is called unnecessary duplication as shown in the following Table No. II.

TABLE NO. II

COMPARISON OF ACTUAL AND THEORETICAL SYSTEMS OF DELIVERY TO OBTAIN AMOUNT OF UNNECESSARY DUPLICATION IN DELIVERY.

City Studied	Actual	Theoretical	Unnecessary Duplication Miles	Per Cent of Unnecessary Duplication
	Total Duplication Miles	Necessary Duplication Miles		
Kalamazoo	330.70	52.50	278.2	84.13
Lansing	202.90	41.78	161.12	79.41
Flint	208.75	107.25	101.50	48.62

From this table we find that there is a great amount of unnecessary duplication present in each of the cities studied. Also there is some necessary duplication which must be considered. The tendency is to consider the percentage of unnecessary duplication entirely as a percentage of inefficiency. In reality it is only the indicator of service demanded by and given to the consumer and has but very little relation to his cost of milk.

UNNECESSARY WAGONS.

As previously stated, size of load plays a very important part in the efficiency of distribution. With the use of a theoretical system as a measure, the number of unnecessary wagons was determined as follows:

An average load was determined for the theoretical system. The size of this load varied in the different cities, but in each case it was estimated as nearly as possible to what could be expected to be a day's work for a man considering seasons of the year. By dividing the milk sold in the city into these theoretical sized loads the number of unnecessary wagons was determined. The difference between the actual number of wagons in use and the number of wagons carrying optimum loads is the number of unnecessary wagons.

TABLE NO. III

A COMPARISON OF THE ACTUAL AND THEORETICAL SYSTEMS OF DELIVERY TO DETERMINE UNNECESSARY WAGONS.

City Studied	Actual	Theoretical	Unnecessary Wagons	Per Cent of Unnecessary Wagons
	Total Number of Retail Wagons	Number of Necessary Wagons		
Kalamazoo	37	21	16	43.24
Lansing	26	19	7	26.92
Flint	45	34	11	24.44

TO DETERMINE OVER DISTRIBUTION.

When we compare unnecessary duplication and unnecessary wagons we find that there is no relation between them. The percentage of unnecessary duplication in Kalamazoo is twice the percentage of unnecessary wagons, while the percentage of unnecessary duplication in Lansing is nearly three times as great as the percentage of unnecessary wagons. In considering over-distribution or inefficiency of delivery the question arises as to which of the two is the indicator. Over-distribution is important only as it affects the cost of milk. To determine which indicates over-distribution we must, therefore, find their relation to the saving of the total cost of milk. Since delivery is but one of the items entering into the cost of milk any saving made by delivery must necessarily be spread over the entire cost of the milk before it has any effect on the entire costs entering into placing milk on the consumer's doorstep. This percentage of saving as shown in the following Table No. IV was figured from the same theoretical system as were unnecessary duplications and unnecessary wagons. This saving in cost of distribution was spread over the total milk costs which includes cost of producing, processing, delivering, investment and managerial ability, with the following results.

TABLE NO. IV

THIS TABLE SHOWS THE RELATION OF UNNECESSARY WAGONS AND UNNECESSARY DUPLICATION TO THE PERCENTAGE OF SAVING OF TOTAL MILK COSTS EFFECTED BY THE ESTABLISHMENT OF A THEORETICAL DISTRIBUTING SYSTEM.

City Studied	Per cent of Unnecessary Duplication	Per cent of Wagons Unnecessary	Per cent Saving
Kalamazoo	84.13	43.24	3.76
Lansing	79.41	26.92	2.26
Flint	48.62	25.00	2.08

From the table we see that the relation between unnecessary wagons and unnecessary duplications was not proportional while an almost direct relation exists between the percentage of saving and the percentage of unnecessary wagons. Since this is true we must conclude that size of load is a much better indicator of efficiency than is duplication of routes.

COMPARATIVE STUDIES.

The relation of the different operations necessary in distributing milk have often been discussed with the idea that there was either directly or inversely a proportion between them. Some of the operations considered proportional were as follows:

1. The miles traveled by the wagons were indirectly proportional to the quarts sold per mile.
2. The time to deliver a load was indirectly proportional to the quarts sold per hour.

3. The time to deliver a load was indirectly proportional to the quarts sold per mile.

4. The miles traveled to deliver a load were indirectly proportional to the quarts sold per hour.

5. The miles traveled to deliver a load were directly proportional to the time required to deliver the load.

6. The quarts sold per mile were indirectly proportional to the quarts sold per hour.

These different operations have been figured out for the different cities studied with the following results.

Table No. V shows that there is very little relation between the miles traveled to deliver the load and the quarts sold per hour of the different dealers in the three cities named. This is accounted for, first, by the personal element met with in the driver, as each driver is of different ability to deliver milk. Second, the kind of vehicle, as an automobile or auto truck is able to cover more territory and give more time for the deliveryman to deliver his milk. Third, the character of territory with regard to kind of roads, accessibility of customer, etc., affects the miles traveled and time of delivery.

TABLE NO. V

The Relation of the Average Number of Miles Traveled per Day per Wagon to the average Number of Quarts Sold per Hour for Each of the Dealers in the Three Cities Studied

Lansing		Kalamazoo		Flint	
Miles Traveled	Qts. Sold per Hour	Miles Traveled	Qts. Sold per Hour	Miles Traveled	Qts. Sold Per Hour
20.5	20.0	14.75	38.38	14.00	59.00
14.5	53.3	14.75	33.73	9.75	34.20
13.35	51.58	14.33	42.63	9.25	38.00
13.25	43.8	14.25	46.00	9.06	40.34
13.00	35.91	12.75	52.88	8.00	40.91
12.86	47.96	10.75	26.22	7.10	14.25
12.00	65.00	10.50	53.8	6.81	61.36
11.64	26.37	9.75	25.6	6.57	44.73
10.3	37.00	9.75	54.3	4.50	85.77
10.0	44.00	9.67	26.51		
7.4	43.44	9.50	54.0		
7.25	41.07	9.50	44.55		
6.1	14.80	9.25	29.75		
		9.25	52.00		
		9.00	50.38		
		8.29	35.18		
		6.00	62.75		
		3.00	31.00		

Table No. VI shows the relation of quarts sold per mile traveled and quarts sold per hour. Here we would expect that the greatest number of quarts sold per mile would tend to increase the number of quarts sold per hour which is approximately true, but is not so in every case, as in Table V the personal element plays the most important part. Tables No. VII, VIII, IX and X, comparing operations in different ways show also that there is no direct relation between operations. Because of the extremes which the comparisons show it would be safe to assume that other influences outside of the necessary labor in the different operations are more responsible for any excess in labor requirements. Some of the influences which tend toward irregularity in distribution are: personal element, character of vehicle, and territory covered—arrangement being made according to importance.

TABLE NO. VI

The Relation of the Average Number of Quarts Sold Per Mile Traveled to the Average Number of Quarts Sold Per Hour By the Different Distributors in the Three Cities Studied

Lansing		Kalamazoo		Flint	
Qts. Sold per Hour	Qts. Sold per Mile	Qts. Sold per Hour	Qts. Sold per Mile	Qts. Sold per Hour	Qts. Sold per Mile
65.00	22.5	62.75	41.83	85.77	42.88
53.30	18.3	54.3	27.85	61.36	42.27
51.58	18.35	54.0	17.05	59.00	12.64
50.0	18.24	53.8	25.62	44.73	25.51
47.96	18.30	52.88	25.92	40.91	16.87
44.00	19.80	52.00	28.11	40.34	19.28
43.80	17.36	50.38	22.39	38.00	5.13
43.44	23.48	46.00	16.14	34.20	17.54
41.07	26.82	44.55	25.79	14.25	4.01
37.00	19.80	42.63	20.33		
35.91	15.80	38.38	16.92		
26.37	18.35	35.18	17.93		
14.80	12.16	33.73	17.15		
		31.00	20.67		
		26.51	13.01		
		29.75	12.86		
		26.22	10.98		
		25.6	13.13		

TABLE NO. VII

THE RELATION OF THE AVERAGE NUMBER OF MILES TRAVELED PER WAGON TO THE AVERAGE NUMBER OF QUARTS SOLD PER MILE FOR THE DIFFERENT DISTRIBUTORS IN THE THREE CITIES STUDIED.

Lansing		Kalamazoo		Flint	
Miles Traveled	Qts. Sold per Mile	Miles Traveled	Qts. Sold per Mile	Miles Traveled	Qts. Sold per Mile
20.50	18.24	14.75	16.92	14.00	12.64
14.50	18.30	14.75	17.15	9.75	17.54
13.35	18.35	14.33	20.33	9.25	5.13
13.25	17.36	14.25	16.14	9.06	19.28
13.00	15.80	12.75	25.92	8.00	16.87
12.86	28.50	10.75	10.98	7.10	4.01
12.00	22.50	10.50	25.62	6.81	42.27
11.64	14.60	9.75	27.85	6.57	25.51
10.3	17.96	9.75	13.13	4.50	42.88
10.0	19.8	9.67	13.01		
7.4	23.48	9.50	25.79		
7.25	26.82	9.50	17.05		
6.1	12.16	9.25	12.86		
		9.25	28.11		
		9.00	22.39		
		8.29	17.93		
		6.00	41.83		
		3.00	20.67		

Table No. VIII

THE RELATION OF THE AVERAGE NUMBER OF HOURS OF DELIVERY PER DAY PER WAGON TO THE AVERAGE NUMBER OF QUARTS SOLD PER HOUR FOR THE DIFFERENT DISTRIBUTORS OF THE THREE CITIES STUDIED.

Lansing		Kalamazoo		Flint	
Hours Delivery	Qts. Sold per Hour	Hours Delivery	Qts. Sold per Hour	Hours Delivery	Qts. Sold per Hour
7.65	47.96	7.50	33.73	5.00	34.20
7.50	50.00	6.83	42.63	3.30	40.91
6.44	26.37	6.50	38.38	3.00	59.00
5.75	35.91	6.25	52.88	2.25	85.77
5.25	43.80	5.50	44.55	2.00	14.25
5.00	53.30	5.00	46.00	1.25	38.00
5.00	37.00	5.00	53.8	4.69	61.36
4.75	51.58	5.00	54.3	4.33	40.34
4.50	44.00	5.00	25.6	3.75	44.73
4.00	65.00	5.00	52.0		
4.00	43.44	4.50	26.22		
3.50	41.07	4.00	29.75		
3.50	14.80	4.00	62.75		
		4.00	50.38		
		3.00	54.00		
		4.75	26.51		
		4.23	35.18		

Table No. IX

THE RELATION OF THE AVERAGE NUMBER OF HOURS OF DELIVERY PER DAY PER WAGON TO THE QUARTS SOLD PER MILE FOR THE DIFFERENT DISTRIBUTORS OF THE THREE CITIES STUDIED

Lansing		Kalamazoo		Flint	
Time of Delivery	Qts. Sold per Mile	Time of Delivery	Qts. Sold per Mile	Time of Delivery	Qts. Sold per Mile
7.65	28.5	7.50	17.15	5.00	17.54
7.50	18.24	6.83	20.33	4.69	42.27
6.44	14.6	6.50	16.92	4.33	19.28
5.75	15.8	6.25	25.92	3.75	25.51
5.25	17.36	5.50	25.79	3.30	16.87
5.00	18.30	5.00	16.14	3.00	12.64
5.00	17.96	5.00	25.62	2.25	42.88
4.75	18.35	5.00	27.85	2.00	4.01
4.50	19.80	5.00	13.13	1.25	5.13
4.00	22.5	5.00	28.11		
4.00	23.48	4.75	13.01		
3.50	26.82	4.50	10.98		
3.50	12.16	4.23	17.93		
		4.00	12.86		
		4.00	41.83		
		4.00	22.39		
		3.00	17.05		
		2.00	20.67		

Table No. X

THE RELATION OF THE AVERAGE NUMBER OF MILES TRAVELED PER DAY PER WAGON TO THE TIME OF DELIVERY PER DAY PER WAGON OF THE DIFFERENT DISTRIBUTORS OF THE THREE CITIES STUDIED.

Lansing		Kalamazoo		Flint	
Miles Traveled	Time of Delivery	Miles Traveled	Time of Delivery	Miles Traveled	Time of Delivery
20.5	7.50	14.75	7.50	14.00	3.00
14.5	5.0	14.75	6.50	9.75	5.00
13.35	4.75	14.33	6.83	9.25	1.25
13.25	5.25	14.25	5.00	9.07	4.33
13.0	5.75	12.75	6.25	8.00	3.30
12.86	7.65	10.75	4.50	7.10	2.00
12.0	4.00	10.50	5.00	6.81	4.69
11.64	6.44	9.75	5.00	6.58	3.75
10.3	5.0	9.75	5.00	4.50	2.25
10.0	4.5	9.68	4.75	....	....
7.4	4.0	9.50	5.50	....	....
7.25	3.50	9.50	3.00	....	....
6.1	3.50	9.25	5.00	....	....
....	....	9.25	4.00	....	....
....	....	9.00	4.00	....	....
....	....	8.29	4.23	....	....
....	....	6.00	4.00	....	....
....	....	3.00	2.00	....	....

EFFECT OF THE AMOUNT OF MILK DELIVERED ON THE EFFICIENCY OF RETAIL DELIVERY.

It is generally supposed that the larger distributors are able to deliver milk more economically than the smaller distributors, mainly because of the opportunity to organize their territory better and thus shorten their routes and avoid duplication. This would then give more time to the driver who would be able to deliver more milk.

Table No. XI was prepared to show how near true this was in actual practice. In the table showing "Miles Traveled per Quart" we find that for the city of Flint the theoretical holds true. For Lansing the same is true with the exception of the 500 to 1,000 quart dealer. This variation is accounted for when we find that only 374 quarts retail milk is delivered. Kalamazoo shows a much greater irregularity than does either of the other two. Here we find the largest distributors traveling more miles per quart than any class of smaller distributors of the same city. There were many things to influence this, perhaps the most important being no workable city ordinance. Some others were: the location of one of the large distributors, credit system, plan of the city, rate of pay and method of payment of drivers.

It would naturally be expected that there would be a direct relation between miles traveled and time of delivery of the different sized distributors which is partly true but in no place consistent. Here the personal element enters in a great deal. The small distributor who usually delivers his own milk does so much faster than the larger distributor who must hire his delivery man. The writer found that smaller distributors with hired delivery men usually required extra work from the men after they returned from delivering. These men made but little effort to get in early because of extra work required of them by so doing.

Table No. XI

MILES TRAVELED PER RETAIL QUART BY DIFFERENT SIZE DISTRIBUTORS.

Distributors Selling	Less than 300 qts.	300 to 400 qts.	400 to 500 qts.	500 to 1,000 qts.	Over 1,000 qts.
Flint	0.08598	....	0.05926	0.03914	0.02514
Lansing	0.05551	0.05035	0.04937	0.05491	0.04134
Kalamazoo	0.05242	0.04378	....	0.04545	0.06315
Average	0.05684	0.04943	0.05095	0.04506	0.03469

TIME IN HOURS TO DELIVER RETAIL QUART BY DIFFERENT SIZE DISTRIBUTORS.

Distributors Selling	Less than 300 qts.	300 to 400 qts.	400 to 500 qts.	500 to 1,000 qts.	Over 1,000 qts.
Flint	0.01771	....	0.02444	0.02107	0.01677
Lansing	0.02288	0.02439	0.02510	0.02005	0.02414
Kalamazoo	0.02366	0.02177	....	0.02309	0.03167
Average	0.02288	0.02234	0.025	0.02203	0.2075

Demands of the Consumer.

Every purchaser of goods reserves to himself the privilege of making his purchases where he chooses. It is the privilege of the housewife to patronize any store or market according to her necessity, preference, or convenience.

Successful business men and merchants know that they must supply the purchaser with the kinds of goods which he wants at the time which he wishes to purchase and in the quantity that he may need. In response to the popular wish every vendor of merchandise attempts to present his goods in terms of the demand. It is the effort of the milk distributor to meet the demands of milk consumers that occasions a large proportion of the popularly considered over-lapping in the distribution of milk. Since it is the nature of people to differ in their likes and dislikes it is not surprising for a consumer to demand a different product than his neighbor, and even individuals in the same family cater to their own desires with different kinds of the same product. Since this exists and will always be with us, we can expect there will always be an effort made to meet these idiosyncrasies. This applies to milk distribution when we find seven different men delivering milk in one eleven-family flat or seven milkmen delivering milk in a block with twelve families. It is not unusual to find a family that takes milk from two milkmen, the reason for this usually being that they want one kind of milk for their baby but prefer a different kind for themselves.

The personal element plays an important part. We must consider the milk deliveryman the salesman for the company. Unlike other commodities where the deliveryman is a cheaper employee for the purpose of delivering the sales of higher priced men, the milkman should be a high class salesman who represents his employer. He must be able to give the necessary service and account daily for all difficulties directly to the customer. This personal contact often is the cause of dissatisfaction to the customer who finds a more congenial milkman to deal with, thus calling an extra distributor to that street.

The policies of the distributor, such as requiring cash or tickets, return of bottles, number of deliveries a day, delivering milk to front doorstep only, early or late delivery, and washed bottles often cause consumers to change milkmen.

There are also some things which cause demand for extra distribution which are unavoidable. Misunderstandings between consumer and dealer or his employee are bound to occur even under the best of conditions. Stolen milk, tickets, or money set on the doorstep are often a cause of trouble, frequently resulting in a change of milkmen. Relatives or friends starting routes in the vicinity usually results in a change. Absorbed flavors getting into the milk unknown to the dealer, breaking down of the plant machinery, and many other reasons that unavoidably occur cause a demand from the consumer for new service with the result of added duplication. Without an opportunity for the consumer to change when these things occur a great amount of dissatisfaction is liable to result.

Because of the fact that milk demands a great amount of work to get it to the customer in a safe desirable form and one of the main requirements of this service is frequent delivery, the milkman is constantly before the eyes of the public. There is no other commodity on the market with so great a demand for or requiring so great an amount of service. This one fact alone should place milk distribution in a position of encouragement rather than of constant antagonism.

The fact that the milkman is so closely associated with the consumer 365 days of the year gives the consumer a more intimate knowledge of milk delivery than of the delivery of any other commodity. It is possible for this reason that milk delivery, more than that of any other article, is unjustly criticised. When compared with other articles we find that there is no logical reason to criticise milk distribution more than the distribution of any other food.

COMPARISON OF THE DELIVERY OF MILK AND BAKED GOODS.

Milk is only one of the commodities delivered to the household and stores of the city. If we compare the service necessary to transport our other food products from the storehouse to the household we shall find that milk and bread are quite comparable in their service requirements.

In baked goods we have an article which must be placed in the hands of the consumer in a fresh condition which requires a daily delivery. Equipment provided for delivery both wholesale and retail is similar. Method of payment of driver is much the same. In general milk requires all the service rendered for the distribution of baked goods and more.

Some things required of milk distribution not required for baked goods are as follows: icing the load, early delivery of retail, heavier loads and heavier work, milk left in stores must be iced, return of bottles and cases, breakage of bottles, greater load of containers, equipment, and Sunday delivery.

From Table No. XII we see that it required about 31 per cent more wagons to distribute approximately the same number of units of milk than it did for a similar number units of baked goods, a unit of milk being equivalent to a quart of milk in value or size. For example, a quart of skimmilk or buttermilk was considered a quart unit, likewise was one-half pint of coffee cream or one-fourth pint of whipping cream. Units of baked goods corresponded very closely to those of milk when the study was started, with a wholesale loaf of bread the same price as a quart of milk, thus making the units comparable. However, soon after the study was started there was a general slackening in the enforcement of war regulations so that the size of a loaf of bread as well as the price was a variable proposition. To overcome this difficulty the total value of the load of baked goods was divided by the price of a quart unit of milk to get the number of units of baked goods so that they might become comparable.

This difference in the number of wagons is not so great when we consider that baked goods is almost entirely wholesale distribution while milk is about one-half wholesale and one-half retail. A short time previous to our study at Kalamazoo, retail delivery of baked goods was practised. There were at that time forty bakery wagons in the city delivering baked goods from door to door much the same as milk is delivered. This was the same number of wagons as was used by the milk distributors of the city at the time the study was made. The eliminating of retail delivery of baked goods took away the consumers service of delivery and put it in the hands of the grocer, at the same cost to the consumer. To put milk on the same system many difficulties are encountered that are not met with in the distribution of baked goods. Milk is a more perishable article and should be used the day it is delivered, thus making daily delivery a necessity. There is greater cost to the storekeeper in handling milk through the stores because of extra cost of refrigeration, lost bottles, soured milk, etc. The extra cost of handling milk through the stores is sufficient to pay for the extra service of delivery necessary to place the milk daily on the doorstep of the consumer and thus avoid all the necessary labor, duplication of labor, and inconvenience required for each separate individual to fetch his own milk from store to home. As shown by Table XIV the extra cost through the stores would be sufficient to pay for the extra number of wagons and service required for retail delivery. Comparing Tables XII and XIV shows that if all of the cities' milk was delivered wholesale the minimum number of wagons (Table XIV) required would be much less than is actually required to deliver baked goods. These figures were obtained by dividing the average number of quart units sold per wagon from wagons carrying wholesale milk only into the total number of quart units for the whole city. The average number of quart units per wagon wholesale being taken from Table No. XV.

TABLE NO. XII

COMPARISON OF THE SERVICE OF DELIVERY RENDERED FOR BAKED GOODS AND MILK.

	Lansing		Kalamazoo		Flint	
	Bakery	Milk	Bakery	Milk	Bakery	Milk
Number of Vehicles	21	31	27	40	45	63
Number of Units Sold	12,989	12,773	13,087	13,481	38,654	29,510
Cost of Delivery Man per Unit	$0.00705	$0.0112	$0.0078	$0.01178	$0.00722	$0.0113
Number of Miles Traveled per Unit	.02245	.029	.0254	.0319	.01687	.01712
Per cent of Duplication of Delivery	57.9	73.27	78.5	76.81	81.2	65.75

In order that the delivery of the two classes of goods could be more easily compared, wagons which used the same system of delivery were selected and compared in Table No. XIII. This table shows that while there is a larger load carried there are also more miles traveled. This comparison is made on wholesale wagons only.

TABLE NO. XIII

COMPARISON OF WHOLESALE BAKERY AND MILK WAGONS OF SAME TYPE AND SAME SYSTEM OF DELIVERY IN FLINT, LANSING AND KALAMAZOO.

	Flint		Kalamazoo		Lansing	
	Bakery	Milk	Bakery	Milk	Bakery	Milk
Number of Vehicles	17	10	9	6	17	3
Average Number of Units Sold per Load	1,197.5	940	888	783	700	952
Average Number of Miles Traveled	12.99	8.09	13.97	10.47	15.85	12.42
Miles Traveled per Unit	.0108	.0086	.0157	.0134	.0226	.0130
Efficient	100%	120%	100%	114%	100%	142%
Stops per Unit	.0332	.03375	.09437	.0157	.0183	.0541

WHOLESALE VS. RETAIL MILK DELIVERY.

There has been a great deal of discussion in regard to the advantage of all wholesale milk delivery over all retail, or wholesale and retail delivery combined. The preceding statements in regard to wholesale delivery give in a general way some of the problems encountered. From Table No. XIV it is evident that for milk to be handled through the stores results in an extra cost in the form of commission to those who dispense it retail. It also adds another dealer through whose hands the milk must pass before it reaches the consumer, the biggest problem in marketing today being the elimination of as many middlemen as prevent economy.

Table No. XIV

COST TO THE CONSUMER TO HAVE ALL HIS MILK HANDLED WHOLESALE THROUGH STORES AND MILK STATIONS.

City	Number of Quarts Sold in City	Number of Wholesale Wagons to Deliver all Milk	Number of Retail Wagons to Deliver all Milk	Commission to Dealers 2c Quart Handling Milk	Number of Retail Wagons 2c Commission Would Hire
Flint	29,510	44	87	$590.19	89
Lansing	12,773	13	38	$255.40	48
Kalamazoo	13,481	14	38	$257.22	45

For storekeepers to handle milk is more or less of an accommodation. Their commission as allowed by milk distributors who compete in the retail business is too small compared with other goods to actually pay. With stores and shops handling all the milk a 30 per cent commission charge could be expected from the stores. Even with the present two cent commission to the stores, which was the general charge at the time this study was made, we find from Table No. XIV that Flint stores handling all of the milk would receive enough commission to support 89 retail wagons. These wagons, with the number already in use distributing the milk wholesale, would make 133 in all, which is 46 more than would be the minimum requirement to distribute all of the milk retail. For these 133 wagons to distribute all of Flint's milk would require an average load of 222 quart units which according to Table No. XV is 30.5 quart units less than the average retail load now delivered. A greater difference than 30.5 quart units will be observed, if the amount of wholesale milk usually carried on retail wagons to make up a load, is added.

Figuring the same way for Lansing, we find that 61 wagons retail could be employed for the same price. These are 23 wagons more than was the minimum requirement to distribute all of Lansing's milk retail. For 61 wagons to distribute the milk would require an average load of 209 quart units which are 40 quart units less than the average retail load now delivered. Besides this most of Lansing's retail wagons carry wholesale milk to account for a load.

For Kalamazoo, 59 wagons could be employed for the same price as would be charged the consumer for wholesale delivery, which are 21 wagons more than the minimum requirement necessary to distribute all of Kalamazoo's milk retail. Fifty-nine wagons would average 228.5 quart units per load to distribute all of Kalamazoo's milk retail. These are 58.5 quart units less than the average retail load now delivered. Kalamazoo, like Lansing and Flint, carries wholesale milk on retail wagons.

Considering the amount of wholesale milk carried on retail wagons for all three cities, it appears that a system of exclusively wholesale delivery of all the cities' milk would cost the consumer as much as a liberal retail distributing system, while a half wholesale and half retail system, such as is now employed, results in an even greater service and saving to the consumer.

TABLE NO. XV.

SHOWING THE EXTREMES OF SERVICE RENDERED FOR MILK DELIVERY IN FLINT, LANSING AND KALAMAZOO.

Retail Deliveries Only	Flint			Lansing			Kalamazoo		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Number of Retail Customers per Wagon	570	33	217.84	554	51	268.65	432	51	204.4
Number of Stops per Wagon	534	33	205.16	538	50	248.34	429	51	201.7
Number of Bottles Sold per Wagon	615	34	271.77	656.4	79	372.00	385	62	336.7
Number of Bottles Delivered per Retail Stop	3.415	.903	1.324	1.78	1.29	1.5424	2.016	.49	1.114
Retail Quarts Sold per Wagon	565	28.5	252.5	430	55	248.96	514	62	287.0
Retail Quarts Sold per Hour per Wagon	121.4	14.25	57.76	65	14.8	42.11	79.33	13.273	33.29
Retail Quarts Sold per Mile per Wagon	94.166	4.014	34.972	37.6	12.16	21.43	50.11	7.522	19.01
Retail Quarts Sold per Stop per Wagon	2.506	.77	1.230	1.48	.8428	1.0023	1.831	.331	.928
Miles Traveled per Retail Load	14.00	3.9	7.22	20.5	6.0	11.6	15.25	3.0	9.84
Miles Traveled per Retail Quart	.249	.0106	.0286	.1173	.0268	.04665	.079	.0132	.0371
Miles Traveled per Stop Retail	.311	.0139	.0352	.0129	.0239	.04676	.1423	.016	.0489
Miles of Self Duplication Retail Load	3.65	.50	1.94	4.0	.35	1.355	5.00	.35	2.04
Per Cent of Self Duplication Retail Load	53.7	4.44	26.85	19.5	5.00	11.60	40.00	6.77	19.16
Time to Deliver Retail Load	9.0	1.25	4.371	10.5	2.00	5.91	7.5	2.00	4.81
Time to Deliver Retail Quart—Minutes	4.206	.492	1.038	4.156	.888	1.5372	3.9	.75	1.55
Value of Retail Load	87.35	4.44	38.61	49.56	7.42	28.64	59.04	7.44	28.33
Deliveryman's Rate of Pay	8.66	1.88	5.09	5.15	3.75	4.44	5.50	3.15	3.94
Wholesale									
Quarts Sold per Wholesale Wagon	1576.5	36.0	667.34	1550.85	247.5	1003.28	1118.5	655.5	951.6
Bottles Delivered per Wholesale Wagon	1808.0	35.0	573.47	1640.47	331.00	966	946	597.5	797.0
Miles Traveled per Wholesale Wagon	21.5	2.5	9.16	21.00	6.5	13.76	18.75	8.0	12.42
Time to Deliver a Wholesale Load—Hours	6.0	.5	3.21	11.0	2.5	7.20	9.0	8.0	8.50
Value of Wholesale Load	223.39	5.11	89.84	145.74	29.70	97.36	132.19	84.54	112.06

CONCLUSIONS.

1. The presence of two or more milk wagons on a street is not proof of waste in milk delivery.

2. Duplication of delivery tends to show the amount of service rendered.

3. Size of load shows efficiency of delivery.

4. The ability of the driver and his equipment determine to a large extent the size of a load.

5. The demand of the consumer is the greatest cause of over-distribution or duplication of routes.

6. Exclusive wholesale delivery or milk stations are not a remedy for the ailments of our present milk delivery system.

7. Milk is but one commodity of a city's food supply subject to extra distribution through demands of the consumer.

ACKNOWLEDGMENTS.

Due credit should be given to Professor A. C. Anderson, former head of the Dairy Department, under whose direction this work was started, and for his advice and assistance through the entire preparation of this bulletin.

The writer also wishes to express his appreciation to the distributors of milk and baked goods in the cities studied. Their co-operation was indispensable in obtaining information and statistics presented herein.

AN EXPERIMENT IN IMPROVING THE MILK SUPPLY OF A CITY MILK PLANT.

(Special Bulletin No. 112)

L. H. COOLEDGE AND O. T. GOODWIN

There has been a strong demand among the milk distributors and dairy manufacturers of the State for a better method of determining the keeping quality of milk, both for city distribution and in the manufacture of dairy products. Investigations of this problem carried on in the Bacteriological Section of this Station have resulted in the development of the pH method by Cooledge and Wyant in 1919. This method measures the activity of certain bacterial types, of importance in the souring of milk, rather than attempting to determine the number of bacteria present. It is being found of value in the improvement of city milk supplies. The following contest was conducted to judge its use in actually improving the city milk supply of East Lansing, Michigan.

Milk contests have been originated in attempts to improve the milk supply of various cities and of city milk plants. These have been based largely upon the results of inspections of dairy farms and milk scoring, by means of the score card. Without doubt these contests have accomplished a great deal in the way of educating the dairy farmer as to proper methods.

Not being satisfied with the above basis for conducting a milk contest, the authors have selected the pH method, originated by Cooledge and Wyant of this Station (1), as being well suited for judging the condition of milk as it arrives at the plant. The pH method attempts to measure the activity of the important acid-producing bacterial groups in the sample rather than to determine the number of bacteria present and this, therefore, checks with the actual keeping quality of the milk, a thing which other methods fail to do.

The simplicity and the low cost, together with the fact that results obtained by this method may be reported to the farmer in terms of hours required for samples to sour, rather than as a term or factor which is meaningless to the uninitiated are other reasons why we favor this method.

EXPERIMENTAL MILK CONTEST.

The time selected for the contest was spring, when the milk usually arrives at the plant in the poorest condition, due, no doubt, to the fact that the farmers are in the habit of depending too much upon the cold weather of winter to cool the milk.

To stimulate interest in the contest, ten prizes, consisting of five and ten pound cheeses, were divided into two classes as follows:

Class A. Under this class 5 prizes were awarded to farmers delivering milk having the highest average pH score during the contest.

Class B. Under this class 5 prizes were awarded to farmers delivering milk showing the greatest improvement during the contest.

Under Class A it was expected to award prizes to those who were delivering a superior grade of milk. Class B was designed to stimulate the interest of patrons whose milk made the poorest showing during the preliminary period.

THE CONTEST WAS DIVIDED INTO TWO PERIODS.

Preliminary period. During this time the samples were taken, in so far as possible, without the knowledge of the farmers. This period lasted four weeks and represented the condition of the milk as it was delivered before the patrons had knowledge of the contest. It was used as a basis for judging improvement during the contest.

Contest proper. Immediately after the preliminary period, the patrons were notified of the contest, told of their average score during the preliminary period and advised as to methods which, if put into practice, might be expected to bring about improvement in the supply. Letters of encouragement and advice were sent to patrons once a week during the contest. These letters told the patrons his average score for the week, and the average score of all the patrons. One week elapsed between the close of the preliminary period and the contest proper.

EXAMINATION OF SAMPLES.

The samples taken during the preliminary period and during the contest proper were examined (1) by the pH method, (2) the bacteriological count, (3) the Weinzirl spore test, and (4) for temperature. Experimental cheeses were also made from the milk delivered in this contest.

(1) THE pH METHOD AND ITS DETERMINATION.

Preparation of Media. The only medium necessary for this work is bouillon cube broth recommended by Wyant (4) containing the indicator. Dibromthymol sulphonephthalein (Brom-thymol blue). This is made as follows One bouillon cube, 1 percent Witte's or other peptone, and 0.5 percent salt are added to each liter of water, this is boiled several minutes and then filtered. 80 cc. of a 0.04 of one percent aqueous solution of bromthymol blue is then added for each liter of broth. The broth is then cooled to 20°C. and the color adjusted to compare with tube 6.8 of the standards which are mentioned later. A compensating blank, broth without indicator, must be placed in front of the standard and the readings must be made at room temperature.

The broth is then placed in 100 or 200 cc. flasks, sterilized, and stored. When needed 10cc. of the broth indicator solution is transferred to a 2.8 x 16 cm. sterile test tube with a 10 cc. sterile pipette and compared with standard tube pH 7.0 in the comparator. A few drops of N/1 NaOH or HCl are then added to the flask of indicator solution if needed to make the color of the broth solution compare with tube pH 7.0. Broth without indicator must be used as a compensating blank, in front of the standard tube. The broth is now ready to use and is transferred in 10 cc. portions to a 2.8 x 16 cm. test tubes using a sterile 10 cc. pipette.

Preparation of samples. It is desired to add 0.1 cc. of milk to each tube of brom-thymol blue broth. To reduce the error due to measuring direct as small an amount of milk as 0.1 cc., sterile 9 cc. water blanks in test tubes are prepared and 1 cc. of the milk to be tested added to these. After thoroughly mixing 1 cc. of each diluted sample is transferred to a tube of the broth.

Incubation. After the 0.1 cc. portions of milk have been added to the tubes containing brom-thymol blue broth they are placed in a water bath or incubator at a temperature of 100°F. Hourly observations are made to detect the first change in color of the indicator due to the development of acidity resulting from the activity of the bacteria and enzymes present. As soon as pronounced changes are noticed, hourly readings are made by placing the tubes containing milk broth indicator in the comparator and comparing with the standard tubes as mentioned below. The samples must be placed in a water bath and cooled to 20°C. before readings are made. Readings should be made at a constant temperature as otherwise they vary somewhat.

Standards. The standards are the buffer solutions described by Clark and Lubs (5). Ten cc. portions are placed in the 2.8 x 16 cm. test tubes with the same amount of indicator, that was placed in each 10 cc. of the broth solution and sealed. In this way the standards will keep for a considerable period. The standards with the following readings are used in this work, pH 7.4, 7.2, 7.0, 6.8, 6.6, 6.4, 6.2, 6.0, and 5.8. These standards may be prepared in any chemical laboratory, or, if one has not the facilities for making, may be obtained from Hynson, Wescott and Dunning of Baltimore at a reasonable price. A suitable comparator accompanies the standards furnished by the above company. If a large number of samples are to be examined the special comparator designel by Cooledge (6) and made by the Central Scientific Company is desirable.

For convenience, samples of milk are given a score depending upon the pH reading as follows.

1 hour reading	pH 5.8	score 20
2 hour reading	pH 5.8	score 25
3 hour reading	pH 5.8	score 30
4 hour reading	pH 5.8	score 35
5 hour reading	pH 5.8	score 40
6 hour reading	pH 5.8	score 45
7 hour reading	pH 5.8	score 50
8 hour reading	pH 5.8	score 55
8 hour reading	pH 5.9	score 60
8 hour reading	pH 6.0	score 65
8 hour reading	pH 6.1	score 70
8 hour reading	pH 6.2	score 75
8 hour reading	pH 6.3	score 80
8 hour reading	pH 6.4	score 85
8 hour reading	pH 6.5	score 90
8 hour reading	pH 6.6	score 95
8 hour reading	pH 6.7	score 100

(2) *Bacteriological count:* One cc. of milk was taken from each sample and the count of the composite sample, so obtained, made by plating, using the standard methods for bacteriological examination of milk (2).

(3) *Weinzirl Spore Test:* The Weinzirl spore test (3) for manurial pollution was made once a week upon each sample during both the preliminary period and the contest proper.

(4) *Temperature:* The mean atmospheric temperature from 6:00 p. m. until 10:00 a. m., the period during which the milk was in the hands of the farmer, was obtained through the local weather bureau.

EXPERIMENTAL CHEESE.

Cheese was made from milk coming from farms producing low score milk to compare with cheese made from milk coming from farm producing high score milk.

pH SCORES FOR PRELIMINARY PERIOD.

The pH scores of the samples of milk delivered during the preliminary period have been tabulated in Table 1. This represents the condition of the milk as it arrived at the plant during the month of March. Few of the patrons were cooling the milk during this period and the high average pH score of 73 was possible because of the moderate temperature during the day and the cool nights. The average mean temperature for the period during which milk was held at the farm was 31°F.

FARM INSPECTION.

A visit to the farms after the completion of this period revealed some rather surprising conditions. The farm producing milk having the highest average keeping quality was the farm from which the least might be expected if judgment were based upon the conditions under which the milk was produced. The stable was dirty, poorly drained and poorly lighted. The barn yard was such that cattle moving about must become fouled with manure and mud. The redeeming features were a milk house and a very careful milker. The milk showed manurial pollution in but two of ten tests made. Another instance, illustrating the opposite extreme, was a farm having excellent equipment for producing a good grade of milk but actually producing a milk with very poor keeping quality. While this man had an excellent stable and everything indicated

TABLE NO. 1.—pH SCORES OF MILK DELIVERED AT CITY MILK PLANT DURING PRELIMINARY PERIOD.

Patron No.	1st week.		2nd week.		3rd week.		4th week.		Average.
	3-7-21	3-10-21	3-16-21	3-18-21	3-22-21	3-23-21	3-29-21	4-1-21	
2	55	50	55	55	85	50	50	55	56.9
8	95	90	50	80	55	80	90	55	74.4
10	100	100	100	95	100	95	100	100	98.8
12	75	80	55	55	90	75	80	75	73.1
14	40	45	40	50	45	40	55	55	46.3
16	90	85	70	100	100	100	90	95	91.3
18	90	90	55	50	45	50	100	95	71.9
20	85	100	50	55	90	80	75	75	76.3
22	95	80	50	50	45	55	100	95	71.3
24	40	40	45	45	45	45	80	70	51.2
26	95	55	90	85	95	90	90	100	87.5
30	85	75	55	85	85	85	95	95	82.5
32	90	85	100	100	100	90	100	100	95.6
34	40	65	85	85	100	70	50	50	68.1
38	85	85	45	55	45	40	80	100	66.9
40	50	85	75	50	55	95	95	95	71.3
42	50	70	45	85	100	95	90	65	75.0
46	50	45	35	40	30	40	65	65	46.3
48	65	75	80	60	100	80	80	85	78.1
72	55	75	45	55	90	50	85	100	69.4
100	50	65	50	90	90	90	90	95	77.5
102	45	90	40	90	75	55	95	100	73.7

TABLE 2.—pH SCORES OF MILK DELIVERED AT CITY MILK PLANT DURING CONTEST PROPER.

Patron No.	1st Week.		2d Week.		3d Week.		4th Week.		5th Week.		6th Week.		Average.
	4–7	4–8	4–13	4–15	4–18	4–20	4–26	4–29	5–4	5–6	5–9	5–12	
2	55	50	55	70	80	55	45	55	90	55	55	65	61.0
8	100	85	95	90	100	90	55	90	90	90	95	90	81.0
10	50	50	100	100	100	90	45	55	95	95	95	90	80.0
12	55	40	75	90	100	85	55	95	100	75	95	90	80.0
14	55	75	95	65	90	90	55	75	95	85	95	90	80.0
16	90	100	90	55	85	80	90	65	90	85	90	75	83.0
18	50	55	90	95	90	95	95	90	55	95	95	100	84.0
20	95	55	100	95	90	90	50	90	90	90	90	85	85.0
22	50	100	95	80	100	100	40	55	90	90	65	55	77.0
24	55	55	50	45	50	50	55	55	50	55	55	55	52.5
26	95	95	95	95	90	90	55	85	90	90	90	90	88.0
30	95	75	100	95	90	95	90	90	90	95	90	90	91.0
32	50	55	95	90	95	90	50	55	95	80	60	95	76.0
34	100	55	55	65	55	45	45	70	90	55	90	55	65.0
38	75	55	100	90	80	55	85	100	90	95	95	90	84.0
40	55	45	85	55	100	75	75	75	90	75	90	90	76.0
42	75	90	90	55	85	90	65	85	55	90	90	90	80.0
46	55	45	55	50	45	45	55	55	95	55	90	90	61.0
48	90	55	65	95	90	90	60	65	95	90	90	95	82.0
72	100	95	90	90	100	90	50	90	95	90	95	70	88.0
100	65	55	95	90	100	85	55	65	95	90	90	85	81.0
102	55	85	90	100	100	95	65	85	95	90	90	90	87.0

that milk produced would be of the best, the milk showed manurial pollution each of the sixteen times that it was tested.

We do not cite these cases to prove that good surroundings are not desirable for the production of clean milk, but as instances, illustrating the often observed fact, that a careless dairy man will produce poor milk under the best of surroundings and that the exceptional dairyman may produce clean milk under the poorest of conditions. We believe, however, and our observations during the contest confirm the belief, that for the average dairyman, the better surroundings the better the milk produced.

MILK SCORES DURING THE CONTEST.

The pH scores of the samples of milk delivered during the contest proper are tabulated as Table II. These represent the condition of the milk as it arrived at the plant during the months of April and part of May. During this time the farmers knew that the contest was in progress, and were receiving weekly letters telling of the contest results and advising them as to methods which might be expected to improve the supply. The average pH score during this period was 78. This is an average improvement of 5 in spite of the fact that the average mean temperature was 22° F. warmer during this period than during the preliminary period.

The effect of the temperature upon the average pH score during the preliminary period and during the contest proper is shown in Chart No. 1.

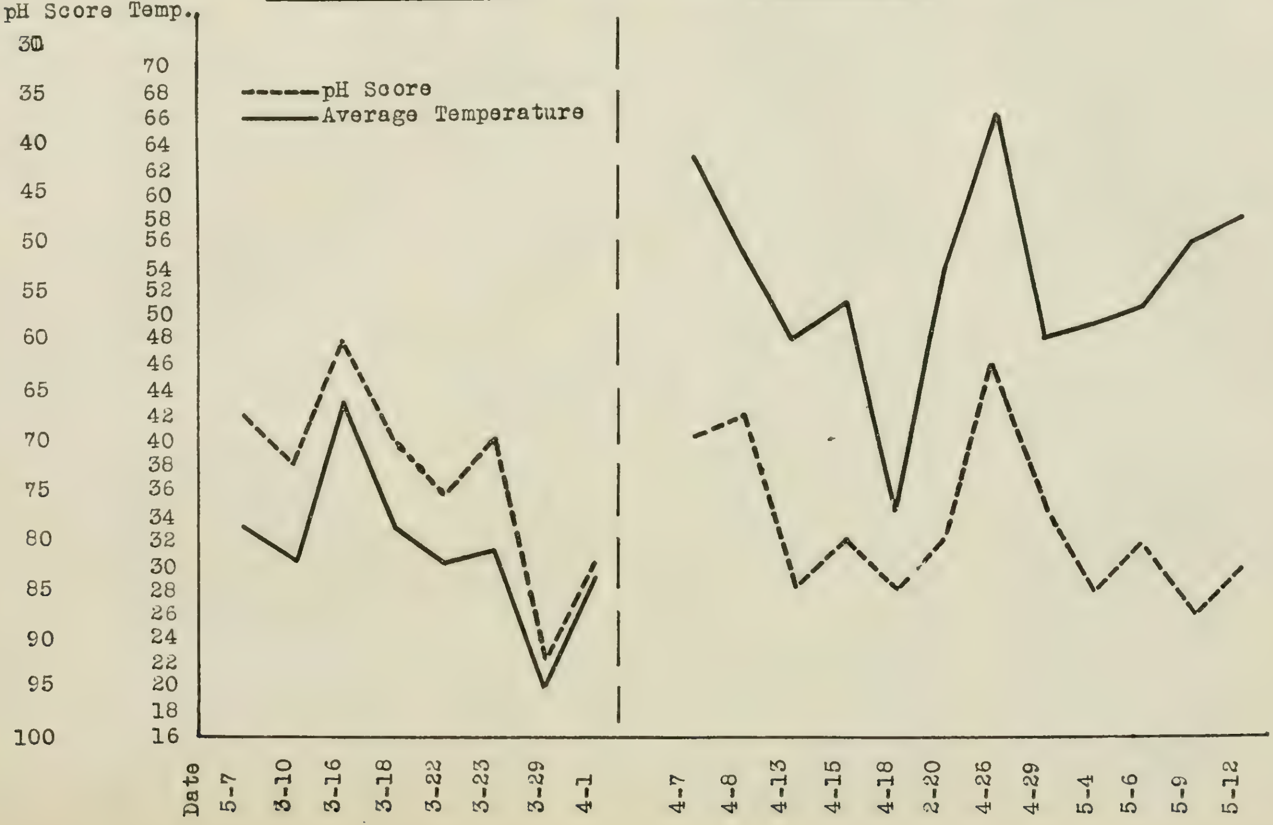
DISCUSSION OF CHART NO. 1.

It will be noted that during the preliminary period a very close relation existed between the atmospheric temperature and the pH score. Later on in the preliminary period the pH score improved slightly as compared with the temperature. This no doubt was due to the fact that when some of the farmers saw samples of their milk taken they became suspicious of something unusual and as a consequence produced the milk with more than the usual care.

The fact that the line, representing the average pH score of the samples of milk, checks so well with the temperature during this period, is a good indicator of the value of this method. A line, representing the bacteriological count when charted in a similar manner, fluctuates from the top of the chart to the bottom showing a very slight tendency to check with the temperature curve. As the temperature is the only important variable during this period, an efficient method should show a close relation to it.

During the contest proper the curve representing the pH score shows a great improvement in relation to the atmospheric temperature curve. As interest in the contest grew the pH score improved even as the temperature became warmer. The average pH score during the contest represented an average improvement over the preliminary period of 5, although the average mean temperature was 22°F. higher. A comparison of results obtained last year with Chart I. indicates that the average pH score this period would have been between 45 and 50 if the contest had not been during this period would have been between 45 and 50 if the contest had not been in progress. Last year, at a corresponding time, several cans

Chart No. 1 Showing relation of Average pH Score and Temperature.



Preliminary Period

Contest Proper

of milk were returned to the farmers because they were sour on arrival at the plant.

CLASSES AND PRIZES AWARDED.

Prizes were awarded under Class A to patrons delivering milk having the highest average pH scores during the contest as follows:

Class A.

1st prize	Patron 30	Average pH score 91
2nd prize	Patron 26	Average pH score 88
3rd prize	Patron 72	Average pH score 88
4th prize	Patron 102	Average pH score 87
5th prize	Patron 20	Average pH score 85

Prizes were awarded for the greatest improvement under Class B as follows:

Class B.

1st prize	Patron 14	Improvement in pH score 34
2nd prize	Patron 38	Improvement in pH score 19
3rd prize	Patron 12	Improvement in pH score 17
4th prize	Patron 46	Improvement in pH score 15
5th prize	Patron 18	Improvement in pH score 12

No patron was awarded a prize in both Class A and Class B.

RESULTS OF THE BACTERIOLOGICAL COUNT

To determine the effect of the contest upon the bacteriological count a one cubic centimeter portion of milk was taken from a representative sample of each patron's milk and the whole mixed and plated. The result is compared with the average pH score each day of the test in Table III.

The bacteriological counts of composite samples of milk made each day of the preliminary period and contest proper indicate a still greater improvement in the milk supply than does the pH score. The average count during the preliminary period was 3,800,000 bacteria per cubic centimeter as compared with an average count of 926,000 during the contest proper.

RESULTS OF THE WEINZIRL SPORE TEST.

In order to obtain data upon the value of the anaerobic spore test for manurial pollution a weekly test was made of milk from each patron according to the method described by Weinzirl (3). The results of these tests are tabulated in Table IV. The samples marked + had typical stormy fermentations in at least two tubes at the end of three days incubation which is to be considered as positive, for manurial pollution. The remaining samples had not more than one tube out of five showing the typical stormy fermentation and indicate negative manurial pollution.

RELATION BETWEEN pH SCORE AND MANUAL POLLUTION.

That there is some connection between the average pH score and the average manurial pollution is indicated by the following facts.

Preliminary period. Of the seven milks showing the least manurial pollution all but two were in very good condition with an average pH

TABLE 3.—COMPARISON OF BACTERIOLOGICAL COUNT AND AVERAGE pH SCORE.

Date.	Bact. per c. c.	Average pH score.
	(Preliminary Period)	
3- 7-21	1,500,000	69.3
3-10-21	11,000,000	74.0
3-16-21	7,500,000	59.8
3-18-21	3,000,000	68.8
3-22-21	5,000,000	75.7
3-23-21	2,500,000	69.0
3-29-21	200,000	83.4
4- 1-21	300,000	82.7
	(Contest Proper)	
4- 7-21	1,700,000	71.1
4- 8-21	6,000,000	66.8
4-13-21	300,000	84.5
4-15-21	500,000	79.8
4-18-21	500,000	87.0
4-20-21	500,000	80.4
4-26-21	1,500,000	60.7
4-29-21	200,000	74.8
5- 4-21	50,000	87.2
5- 6-21	100,000	82.2
5- 9-21	70,000	85.9
5-12-21	200,000	82.95

TABLE 4.—MANURIAL POLLUTION AS INDICATED BY THE WEINZIRL ANAEROBIC SPORE TEST.

Patron No.	Preliminary Period.				Contest Proper.					
	Weeks.				Weeks.					
	1st.	2d.	3d.	4th.	1st.	2d.	3d.	4th.	5th.	6th.
2	+	+	+	+	+	+	+	+	+	+
8	+	+	−	+	−	−	+	+	−	−
10	+	−	−	−	−	−	−	−	+	−
12	+	+	+	+	+	+	+	+	+	+
14	+	+	+	−	−	+	+	−	−	−
16	+	−	−	−	−	−	−	−	−	−
18	+	+	+	+	+	+	+	+	+	−
20	+	−	−	+	+	+	+	−	+	−
22	−	+	+	−	+	+	+	+	+	−
24	+	+	+	+	+	+	+	+	+	−
26	+	−	−	−	−	−	−	−	+	−
30	−	+	−	−	−	−	−	−	−	−
32	+	−	+	−	−	−	−	−	−	−
34	+	+	+	+	+	+	+	+	+	+
38	+	−	−	−	+	+	+	+	+	−
40	−	+	+	+	+	+	+	+	+	+
42	+	+	+	+	+	+	+	+	+	−
46	−	−	−	−	−	−	−	+	−	−
48	−	−	−	−	−	−	−	−	−	−
72	+	+	−	+	+	+	+	−	−	+
100	+	−	−	−	−	−	−	−	+	−
102	+	+	+	+	+	+	+	+	−	−

score of about 75. Of the seven milks showing most manurial pollution all had average pH scores under 76 for the period of the test.

Contest proper. The four milks showing manuarial pollution each week of the contest had an average pH score of 75. The four milks showing no manurial pollution during the contest had average pH score of 83.

The table also shows that some of the patrons produced polluted milk but owing to quick cooling the pH score as it reached the milk plant was quite satisfactory. On the other hand some of the samples showing little manurial pollution were not properly cooled and arrived at the plant in poor condition insofar as their keeping quality was concerned.

The results obtained indicate that the Weinzirl test may be of value when used with the pH test for keeping quality. The Weinzirl test is designed to tell something about the care exercised at the stables and the pH test indicates the care in handling the milk until the time of sampling.

CHEESE MAKING AND THE pH SCORE.

To see in what way the suitability of milk for cheese making was affected by its keeping quality as determined by its pH score experimental cheeses were made as follows:

Cheese No. 1 made from milk having an average pH score of 96.2 had a quality score of 94.

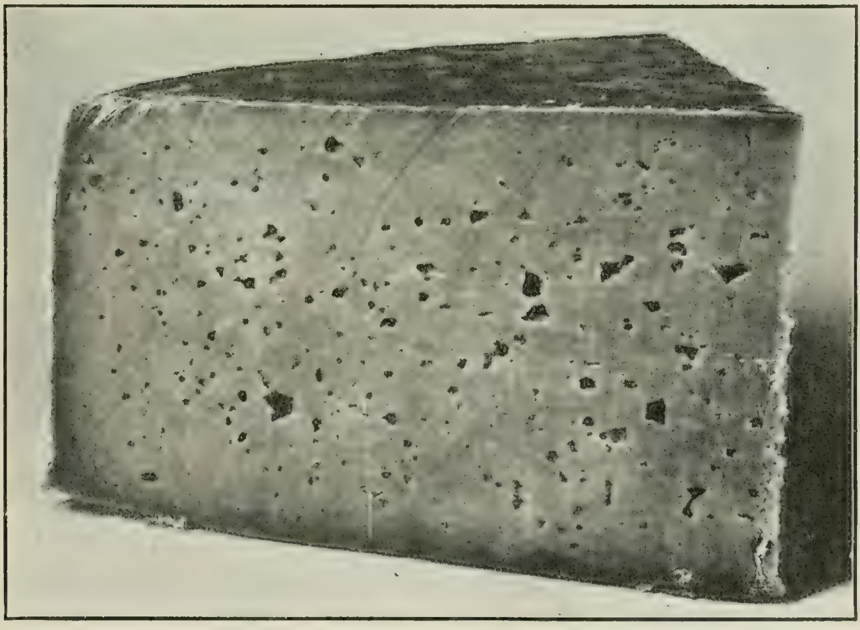


Fig 1.—Cheese No. 1, Milk scoring 96.2 pH method. Cheese scored 94.

Cheese No. 2 made from milk having an average pH score of 66.6 had a quality score of 88.

Cheese No. 1 had a closer texture with fewer gas holes and had a cleaner flavor.

The fact that the cheese made from milk having a low pH score was less satisfactory than the cheese from high scoring milk is probably not due to the greater activity of the acid organisms present, but rather due to the fact that the high scoring milk was carefully produced while the low scoring milk was produced in such a careless way as to permit the entrance of the gas producing organisms so unwelcome to the cheese maker.

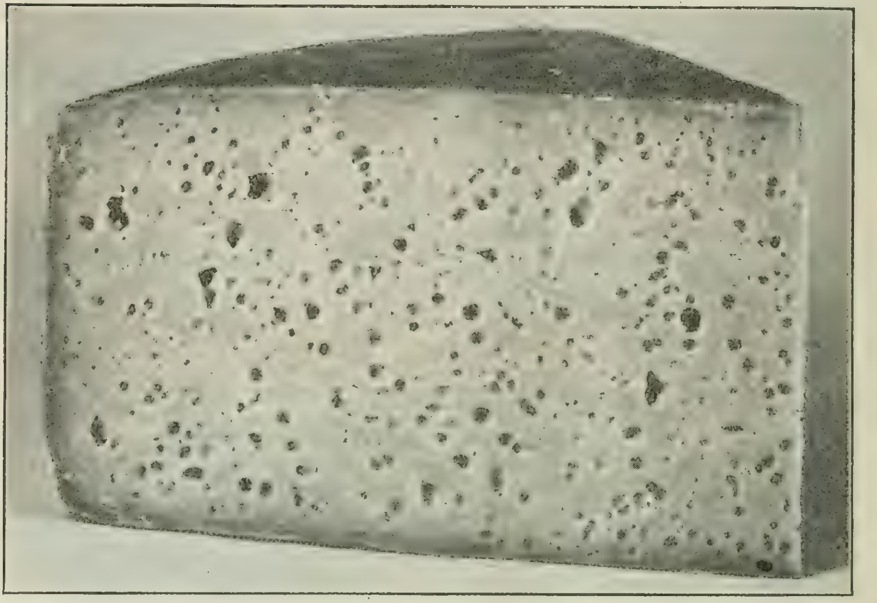


Fig 2.—Cheese No. 2, Milk scoring 66.6 pH method. Cheese scored 88.

SUMMARY.

The pH score proved a very satisfactory basis for judging a milk contest.

The contest was a success in that nearly every producer made a successful attempt to improve the keeping quality of milk delivered in spite of warmer weather.

The Weinzirl anaerobic spore test promises to be of value when used in connection with the pH method.

Milk delivered with a low pH score made less satisfactory cheese than milk having a high pH score.

Before the patrons knew of the contest there was a close relation between the average pH score and the mean atmospheric temperature at which milk was held.

REFERENCES.

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(2) Standard Methods for the Bacteriological Examination of Milk. American Public Health Association 1921.

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(4) Wyant, Zae N. Journal of Bacteriology, Vol. V, No. 3, March 1920.

(5) Clark Wm. M., and Lubs, H. A. Journal of Bacteriology ii, Nos. 1, 2, and 3. 1917.

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SWEET CLOVER.*

Special Bulletin No. 113.

C. R. MEGEE.

Sweet clover has long been recognized as a forage crop but only recently has its value been appreciated and a place allotted it in our agricultural program. The principal causes for the lack of appreciation of this crop are (1) the tendency of the stems to become very coarse and woody upon coming into blossom, (2) its aggressiveness on many waste places and (3) the bitter taste which makes it unpalatable until stock have become accustomed to it.

If a hay crop is desired the coarse, woody stems may be almost entirely eliminated by cutting at the proper time. The aggressiveness of the plant makes it very valuable as a soil improver, especially upon lands that have been cultivated over a long period and are low in organic matter and available plant food. Sweet clover does not become a pest in cultivated fields or pastures. Stock will become accustomed to the peculiar taste of sweet clover in a very few days and will eat the hay or pasture as readily as clover or blue-grass.

A SOIL BUILDER.

Sweet clover belongs to the group of plants known as legumes, which when inoculated have the ability of making use of the free nitrogen of the air and storing it in the plant tissue. This is very important in crop production because nitrogen is one of the essential elements for plant growth and the most expensive element purchased in a complete fertilizer.

Through the proper use of leguminous plants such as sweet clover, alfalfa and red clover, it is possible to largely eliminate the need of purchasing nitrogen in the form of a commercial fertilizer. The same organism that inoculates sweet clover also inoculates alfalfa, thus sweet clover is a valuable crop to precede alfalfa.

Sweet clover is valuable as a soil improver because it will grow on soils that are quite low in fertility and deficient in organic matter, provided they are well supplied with lime. For this reason it is one of the best crops for building up light soils and poor, heavily cropped soils that are low in fertility, whether heavy or light.

A VALUABLE PASTURE CROP.

When properly handled sweet clover furnishes an abundance of pasturage from early spring until late fall. Unlike alfalfa it seldom causes bloat. Though stock may not at first take readily to this crop, they will become accustomed to it if fed no other forage or roughage for a few days. Cattle often crave some dry roughage, while being pastured on this crop on account of its succulent nature. The amount of pasturage secured from sweet clover during late July and August, when Kentucky blue grass or June-grass is in the resting stage, is very satisfactory.

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*The term "sweet clover" in this bulletin refers to the biennial white sweet clover.

During the summer of 1921 the Farm Crops and Dairy Sections of this Station co-operated in conducting a feeding trial of biennial white sweet clover as a pasture crop. The cows received approximately one pound of grain for each four pounds of milk produced and were on pasture continuously except while being milked or weighed.

They received no silage or other roughage except that secured from the sweet clover pasture. Sixty-nine dollars worth of milk, at 20 cents per gallon, was produced from one acre of sweet clover after deducting the cost of grain at the rate of $40.00 per ton. With butter fat at 40 cents per pound, the cows produced $26.02 worth of fat per acre of sweet clover after the cost of the grain was deducted.

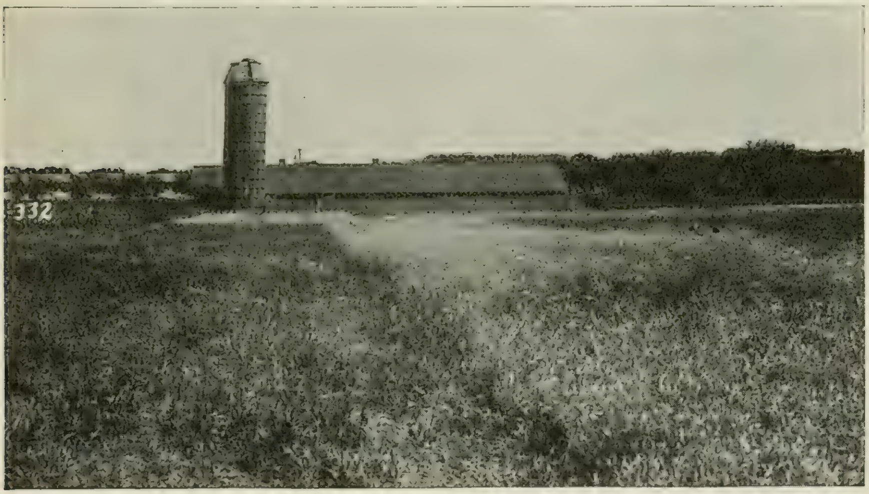

Fig. 2. A sweet clover stand may be completely killed out if the first crop of the second year is cut too short.
To the right—Plat cut eight inches high and the second crop is in full bloom.
To the left—Plat cut four inches high and the stand completely killed out, the sweet clover was replaced by fox tail and other weeds.

A HIGH PROTEIN HAY CROP.

The stage of growth at which sweet clover is cut for hay influences very greatly the quality of hay secured. (See harvesting for hay, page 400.) When cut at the proper stage it contains practically as much digestible protein as alfalfa and more than red clover and the quality and quantity of milk produced when the hay is fed to cows are approximately the same as when other legumes are used (1).* The total yield of sweet clover hay per acre is usually less than from alfalfa, but more than that secured from the true clovers.

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*Refers to reference, see bibliography, page 404.

PRODUCES SEED ABUNDANTLY.

The yield of seed secured per acre is quite high when compared with alsike and red clover. When sown broadcast a yield of from three to five bushels of seed per acre is not uncommon and when drilled in rows yields of from eight to ten bushels are sometimes secured.

A VALUABLE HONEY CROP.

Sweet clover has long been recognized by bee-keepers as one of their valuable sources of nectar. The period of nectar secretion usually follows that of white and alsike clover. The honey from white sweet clover is light in color, with a slight green tint and the yield is heavy.

ADVANTAGES OF SWEET CLOVER.

Sweet clover will grow on practically all soil types provided the soil is not acid and is well inoculated. It will grow on soils that are so low in fertility that alfalfa and red clover will not catch readily and is a valuable crop to pave the way for alfalfa. Sweet clover is equally as drought resistant as alfalfa and more so than red clover. It is equally as winter hardy as alfalfa and red clover.

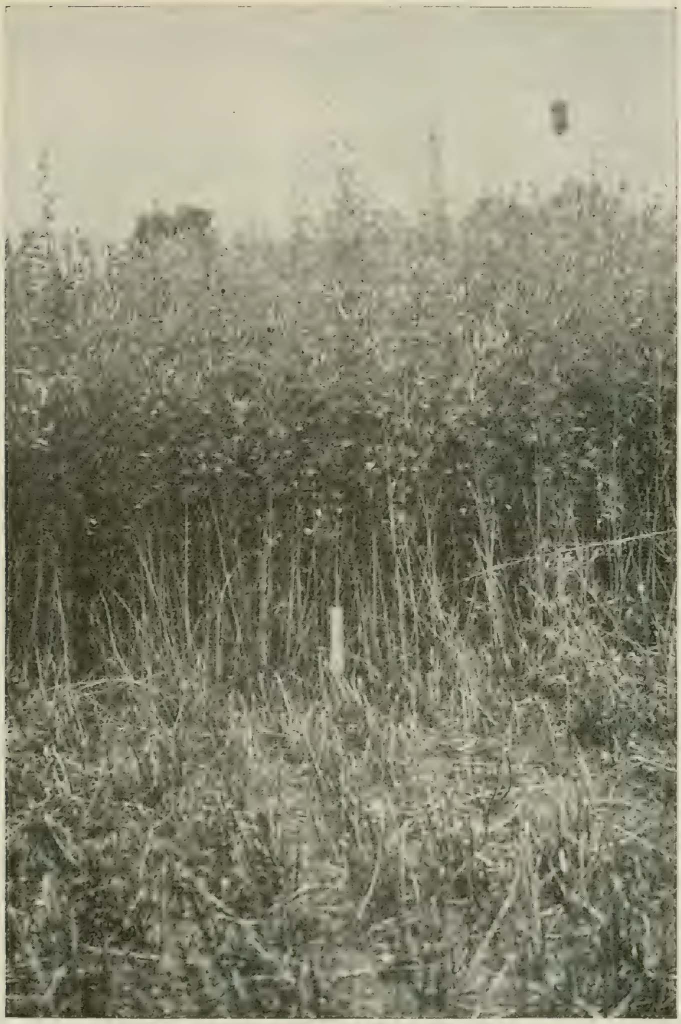
Species of Sweet Clover.

There are three species of sweet clover. The biennial white is the one commonly referred to as "sweet clover" and has proved to be much better adapted to Michigan conditions than either the biennial yellow or annual yellow species. The biennial white has a white blossom, an upright habit of growth and matures seed the second year. The biennial yellow has yellow blossoms, finer stems, is much more decumbent in habits of growth and only yields from one-half to two-thirds as much forage as the biennial white.

Seed of the biennial white is sometimes adulterated with the seed of the biennial yellow. This adulteration may be distinguished by the dark purplish-green mottling and frequent purplish green spots on the seed of the biennial yellow.

The annual yellow is a small erect growing plant, producing seed the first season and should not be sown in this State because of the very small growth secured. The seed of the annual yellow is smaller than that of the other sweet clovers. The annual white sweet clover (trade name Hubam) produces seed the first year and is thought to be a strain of the biennial white.

Hubam has only very recently come into prominence and at this time (1921) has not been tested sufficiently to determine its value.



TOO MATURE FOR HAY.

Fig. 3. When harvesting is delayed until the plants are in full bloom the stems become woody and the leaves drop off, making a hay of poor quality. Sweet clover should be harvested before the blossom buds appear.

LIME AND FERTILIZERS.

Satisfactory yields of sweet clover are very seldom secured on acid soils. Even though the stand may be fair at first the plants will be stunted in growth and but a small amount of hay or pasture secured. When the soil is in this condition it usually requires from one to three tons of ground limestone or from three to six cubic yards of marl per acre to secure good results. The average application of ground limestone is approximately two tons per acre.

Fertilizer tests conducted by the Soils Section of this Station, (5) indicate that on muck soils that are low in phosphorus and potassium the use of a fertilizer may be of value.

TABLE 1—INCREASE IN YIELD OF AIR DRY HAY FROM AN APPLICATION OF PHOSPHORUS AND POTASSIUM ON A MUCK SOIL THAT WAS SEVEN FEET DEEP.

Treatment	Pounds Air Dry Hay per Acre First Year's Growth.
None	960
250 pounds of 16% acid phosphate	2,780
200 pounds of muriate of potash	1,600
250 pounds of 16% acid phosphate and 200 pounds of muriate of potash	2,960

In another test (5) the application of neither manure nor fertilizer produced a satisfactory gain on a deep virgin, muck soil, the unfertilized portion producing 4,265 pounds of air dry hay per acre the first season.

In tests conducted by the Soils Section at the Cass County Farm on sandy land, better seedings were secured where phosphate and potash fertilizers were added along with some form of lime. When ground limestone was used the stand and thriftiness of the plants varied with the fineness of the limestone, those receiving the finely ground limestone being the best. It was also observed that the amount of rainfall influenced the efficiency of the liming material. When lime was applied during a season of minimum rainfall but little benefit was secured from the application of the lime that season while on an adjacent plot that had been limed the year before but seeded during the season of low rainfall a good stand was obtained.

TABLE 2—THE RELATIVE YIELD SECURED FROM THE USE OF DIFFERENT FORMS OF LIME AND DIFFERENT DEGREES OF FINENESS OF GROUND LIMESTONE AT THE CASS COUNTY FARM.

Treatment.		Yields in Pounds of Green Weight per Acre. Year 1921.
Hydrated lime	2,960 pounds per acre	6,640
Marl	4,000 pounds per acre	5,840
Ground limestone, fineness 80 mesh	4,000 pounds per acre	4,280
Ground limestone, fineness, 40–60 mesh	4,000 pounds per acre	3,280
Ground limestone, fineness, 10–20 mesh	4,000 pounds per acre	3,440

In the above test the yields of sweet clover were secured five years after the lime was applied. The lime was applied as the land was being prepared for soybeans. Rye and wheat followed the soybeans. In addition all plats received 200 pounds of acid phosphate per acre previous to soybeans and wheat and 100 pounds of sodium nitrate per acre previous to soybeans, rye and wheat. The difference in yield due to the application of different forms of lime and degree of fineness of ground limestone was more striking with the rye and wheat than with the sweet clover. The necessity of applying lime for sweet clover on this type of soil, however, is very apparent since it was impossible to get a stand of sweet clover on those plats that received no lime.

In the fertilizer test conducted by the Soils Section at the Cass County Farm the rotation consisted of soybeans, rye, wheat, sweet clover. Acid phosphate was applied to soybeans and wheat. Sodium nitrate was applied to soybeans, rye and wheat and potassium chloride to the soy beans.

TABLE 3—LIGHT SANDY SOILS RESPOND QUITE READILY TO LIME AND POTASH—CASS COUNTY FARM.

Plat No.	Treatment.	Yield of Sweet Clover. Green Weight per Acre Ave. 1920–1921.
1	Neither lime nor fertilizer applied	Seeding total failure.
1s	Ground limestone 6,300 pounds per acre	3,508
2	Ground limestone 6,300 pounds per acre Acid phosphate 200 pounds per acre Sodium nitrate 100 pounds per acre Potassium chloride 100 pounds per acre	7,544
3	Ground limestone 6,300 pounds per acre Acid phosphate 200 pounds per acre Sodium nitrate 100 pounds per acre	4,476
4	Ground limestone 6,300 pounds per acre Sodium nitrate 100 pounds per acre Potassium chloride 100 pounds per acre	6,736
5	Ground limestone 6,300 pounds per acre Acid phosphate 200 pounds per acre Potassium chloride 100 pounds per acre	6,158
6	Neither lime nor fertilizer applied	Seeding total failure.
6s	Ground limestone 6,300 pounds per acre	5,248
7	Ground limestone 6,300 pounds per acre Sodium nitrate 100 pounds per acre	4,872
8	Ground limestone 6,300 pounds per acre Potassium chloride 100 pounds per acre	6,456
9	Ground limestone 6,300 pounds per acre Acid phosphate 200 pounds per acre	3,885
10	Ground limestone 6,300 pounds per acre Rock phosphate 1,000 pounds per acre	3,360
11	Neither lime nor fertilizer applied	Seeding total failure.
11s	Ground limestone 6,300 pounds per acre	3,800

The four highest yielding plats received ground limestone and potassium chloride either in combination with sodium nitrate and acid phosphate or alone. The third highest yielding plat received only lime and potash. None of the other plats received potash. Three plats received neither lime nor fertilizer and on these plats the sweet clover seeding was a total failure. The results secured from the use of the fertilizer on the rye and wheat were also quite pronounced.

INOCULATION.

If neither sweet clover nor alfalfa has been grown successfully on the field, artificial inoculation should be made. Since inoculation enables sweet clover to make use of the free nitrogen of the air, it is especially important to inoculate when seeding on soils low in nitrogen and organic matter. There are several different methods of inoculation, the pure culture being the simplest and easiest to apply. Material for the pure culture method may be secured from the Department of Bacteriology of the Michigan Agricultural College, East Lansing, Mich. The price is twenty-five cents per bottle and one bottle is sufficient to inoculate one bushel of seed. Directions for applying this material accompany the bottle.

The soil method of inoculation consists in dissolving one and one-half ounces of carpenter's glue in a quart of warm water and sprinkling it over a bushel of seed, which has been spread out on a smooth floor. Stir the seed and then sprinkle over the seed about a quart of very fine soil that has been recently obtained from a sweet clover or alfalfa field where the roots were heavily loaded with nodules.

Scarification.

A high percentage of sweet clover seed have a seed coat that is quite impervious to moisture and when the seed is sown during the spring or summer, will prohibit its germination that season. When the seed is sown during the late fall the freezing and thawing action of the soil moisture during the winter tends to break the seed coat and germination takes place during the early spring. Unscarified seed usually gives better results when sown during the late fall than does scarified seed. Scarified seed is much to be preferred for spring seedings. The Ames scarifier is the most efficient method of scarification.

Seeding.

A greater growth and a more lasting stand is usually secured by seeding in the early spring on a well-compacted seed bed. Loose seed beds are responsible for many failures. Sweet clover may be seeded in the early spring on fall sown wheat or rye or with barley or oats. A better seeding is often secured by sowing only a bushel of barley or oats when used as a companion crop.

From twelve to fifteen pounds of scarified sweet clover seed per acre is usually sufficient to give a good stand. Ten pounds of high quality scarified seed is sufficient under favorable conditions. From sixteen to eighteen pounds of unscarified seed or from twenty to twenty-five pounds of unhulled seed is usually sufficient to secure a stand.

On fertile soils, sweet clover when seeded at the same time as oats, sometimes makes such a large growth that the curing of the grain is made difficult. On this type of soil it is advisable to seed the sweet clover two weeks later than the oats.

Harvesting for Hay.

The stage of growth at which sweet clover is cut determines very largely the quality of hay secured. **Sweet clover should be cut just before the blossom buds appear.** If allowed to come into bloom, the stems become woody, the leaves fall off and a very poor quality of hay results. **The height of cutting is very important.** The second year sweet clover does not propagate from a crown as does alfalfa, but propagates from buds in the axils of the branches and leaves on the lower portion of the stalk. If the first cutting of the second year is made below the young branches, which bear the leaves, the stand will be destroyed and the second crop will not be secured.

TABLE 4—RESULTS SECURED THE PAST SEASON FROM CUTTING A FIELD OF SWEET CLOVER ON THE COLLEGE FARM AT VARIOUS HEIGHTS AND AT DIFFERENT STAGES OF MATURITY.*

Stage of Maturity.	Height of Cutting.		
	3½ inches.	5½ to 6 inches	9 inches.
Before blossom.....	Stand destroyed.....	Stand only slightly injured......	Stand not injured.
Beginning to blossom	Stand destroyed.....	Stand nearly destroyed.........	Stand not injured.
Full bloom.........	Stand destroyed.....	Stand destroyed...............	Stand nearly destroyed

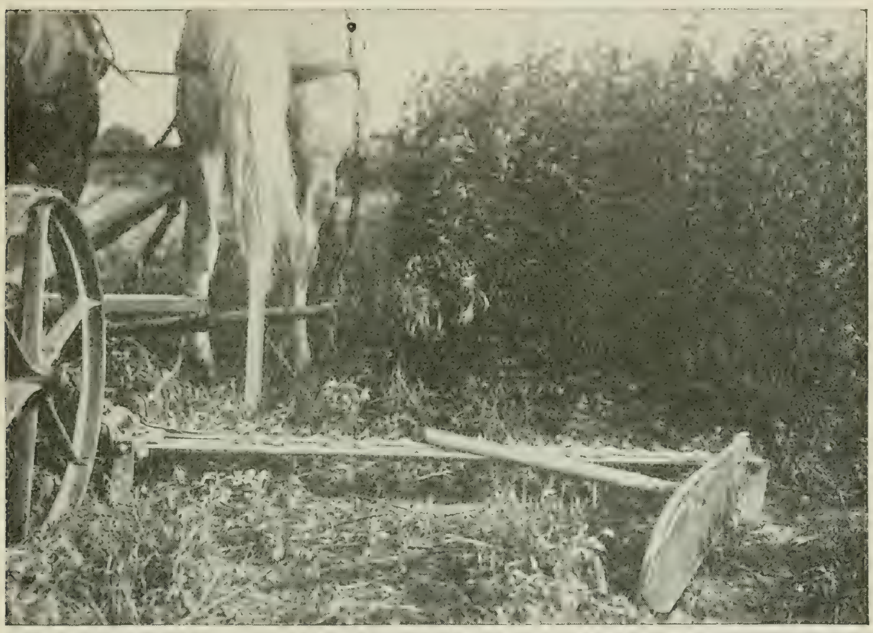


Fig. 4. Special shoes shown in Fig. 6 attached to the cutting bar. In order to secure a second crop the second year, the first crop of the second year should be cut from six to eight inches above the ground.

From the above mentioned test it is clearly evident that sweet clover should be cut just before the blossom buds appear and from six to eight inches high or sufficiently high that a few leaves will be left attached to the stubble. If a seven or eight-inch stubble is desired it will be necessary to replace the shoe soles of the mower with higher soles which may be made of strap iron at any blacksmith's shop. The extension shoe soles used at this Station are shown in Fig. 5.

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*Partial report of project conducted by J. F. Cox and C. R. Megee.

CURING SWEET CLOVER HAY.

Sweet clover is more difficult to cure into hay than either alfalfa or red clover. This is largely due to the large amount of moisture contained within the plant at the time of cutting, causing the shattering of the leaves from the stems before the stems have cured out. That the leaves constitute the best part of the hay is shown by the following analyses.

TABLE 5—AVERAGE ANALYSES OF THE LEAVES AND STEMS OF FOUR SAMPLES OF WELL CURED BIENNIAL WHITE SWEET CLOVER HAY (1). ANALYSES MADE BY THE BUREAU OF CHEMISTRY, UNITED STATES DEPARTMENT OF AGRICULTURE.

Samples.	Moisture.	Ash.	Ether extract.	Protein.	Crude fiber.	Nitrogen free extract.
Leaves..........................	8.70	10.92	3.09	28.20	9.28	39.78
Stems..........................	8.70	8.08	0.70	10.16	39.45	33.08

The samples represented the first cutting the second season. The protein content of the leaves is nearly three times that of the stems, while the crude fiber content of the stems is over four times that of the leaves.

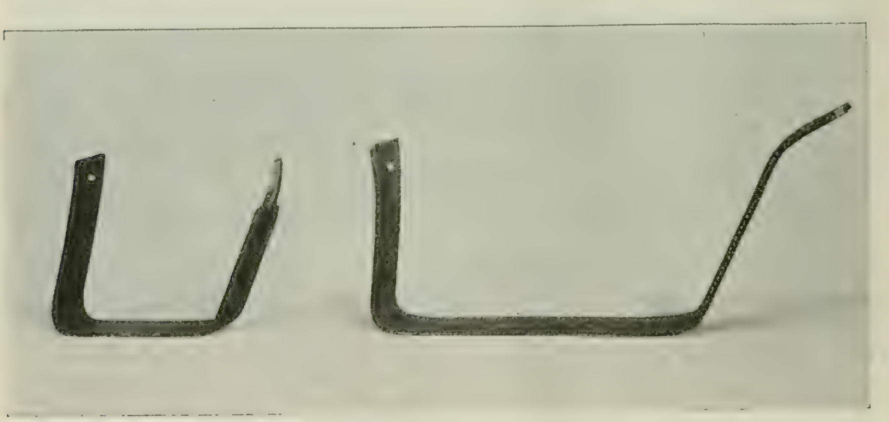

Fig. 5. Shoes such as these may be made at any blacksmith shop and are used to raise the cutting bar in order that sweet clover hay may be cut from six to eight inches above the ground.

One of the most successful methods of curing sweet clover hay is to allow the plants to wilt in the swath, then windrow with a side delivery hay rake and a few hours later place in small upright cocks. The hay should be in cocks before the leaves have dried out sufficiently to crumble or shatter. The hay is then left in the cock until cured sufficiently to put into the barn or stack. This may be only two or three days or may be two weeks depending upon weather conditions. The small cocks may be handled with practically no loss of leaf.

HARVESTING FOR SEED.

The best implement to use in harvesting sweet clover for seed will depend upon the growth made. If the growth is not too rank and heavy the grain binder may be used. However, if very rank the corn binder will give better satisfaction. A three foot swath may be cut with the corn binder when the sweet clover has been broadcasted by placing ten-inch extensions upon the dividers. The mowing machine causes great loss of seed through shattering and is not satisfactory. Regardless of the implement used the shattering will not be nearly so great if the plants are harvested when toughened by a light mist or dew. At this stage of growth most of the leaves have fallen off and no difficulty is experienced in curing. A sweet clover plant does not mature all of its seed at one time, consequently the proper stage at which to harvest is when from 60 to 75 per cent of the seed pods have turned brown.

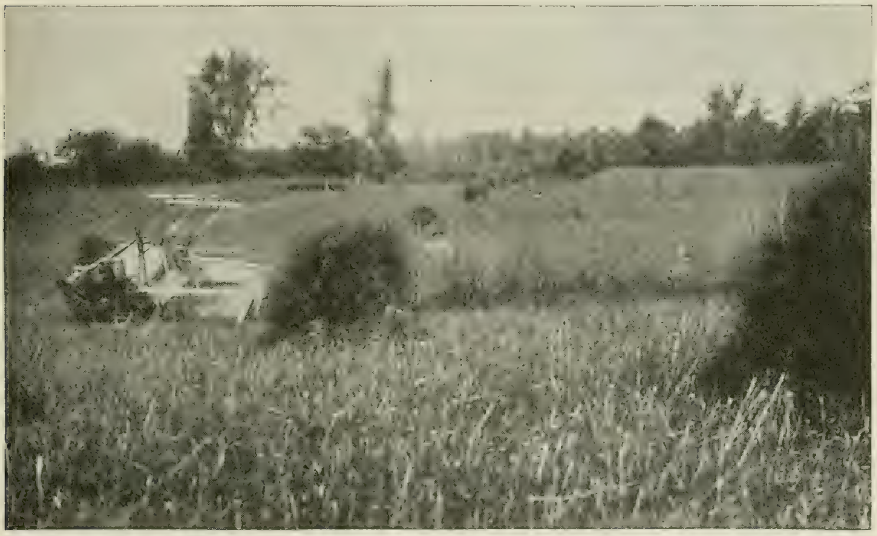

Fig. 6. Harvesting sweet clover seed with grain binder in Alpena County. When the growth is not too rank the grain binder is one of the best implements to use for harvesting sweet clover seed.

Sweet clover seed may be threshed with the ordinary grain thresher. If very dry most of the seed will be hulled, if slightly damp very few seed will be hulled. When the grain thresher does not remove the hull it may be removed with a clover huller or a sweet clover seed scarifier. Due to the greater capacity of the grain thresher it is better adapted for threshing sweet clover than the clover huller.

SWEET CLOVER IS WELL ADAPTED TO MICHIGAN ROTATIONS.

Many farmers have observed the aggressive habit of sweet clover along railroad embankments, roadsides and on clay knolls where the top soil has been removed and have thus become prejudiced against it, fearing it would be difficult to completely eradicate the crop when the land was to be sown to corn, beets, beans, etc. Coe (2) states that the results obtained annually by hundreds of farmers are sufficient proof that there is no foundation for such fear. "When the first year's growth of sweet clover is to be turned under for green manure it is recommended that the field be plowed after the plants have made some growth the following spring rather than in the fall of the year of seeding. When the first year's growth is plowed under the same fall many of the plants will not be entirely covered, and these will make a vigorous growth the following spring. When the plowing is delayed until the plants have made some growth the following spring, no trouble will be experienced in eradicating them."

PUBLICATIONS OF THE MICHIGAN AGRICULTURAL EXPERIMENT STATION RELATING TO THE CULTURE OF LEGUMES.

Alfalfa—Bulletin No. 97.
Soybeans—Special Bulletin No. 100.
Short Season Hay Crops—Circ. No. 42.
Lime, Its Uses and Functions—Special Bulletin No. 91.
The Use of Phosphorus—Regular Bulletin No. 284.
Soil Fertility—Regular Bulletin No. 290.

THE FOLLOWING PUBLICATIONS HAVE BEEN REFERRED TO IN THIS BULLETIN:

(1) Coe, H. S. Sweet Clover: Utilization.
1917—Farmers Bulletin 820, 1-32.
(2) ———— Sweet Clover: Growing The Crop.
1917—Farmers Bulletin 797, 1-34.
(3) ———— Sweet Clover: Harvesting and Threshing The Seed.
1917—Farmers Bulletin 836, 1-23.
(4) Drake, J. A., and Rundles, J. C. Sweet Clover On Corn Belt Farms.
1919. Farmers Bulletin 1005, 1-28.
(5) McCool, M. M., and Harmer, P. M.
Some Results From Fertilizers On Muck Soils.
1921 Quarterly Bulletin.
Michigan Agricultural Experiment Station 4-2: 45-51.

SPRAY AND PRACTICE OUTLINE.

Special Bulletin No. 114.

BY C. P. HALLIGAN, R. H. PETTIT AND G. H. COONS.

SPRAYING APPLE ORCHARDS.

DORMANT SPRAY.

A "dormant" spray should be applied to all orchards where oystershell, San Jose, scurfy or other scale insects are found. The oystershell scale in the commercial apple orchards of Michigan is now more common than for many years past, and San Jose scale has again become more prevalent the past year. While growers who are positive that no scale is present may omit this spray, it is a safe practice to annually apply a dormant spray. Growers should inspect their orchards carefully during the winter or early spring to see if any of these scales are present thus necessitating the application of a "dormant" spray. If you cannot identify these scales, send twigs or a strip of the bark to the Entomologist, Michigan Agriculture Experiment Station, East Lansing, where they will be identified for you free of charge.

The "dormant" spray, if scale is found, should be put on in early spring just before the buds show green. The later it is applied without injury to the trees, the greater its efficiency as an insecticide and fungicide. Lime-sulphur solution (6¼-50), Scalecide, or Soluble Sulphur may be used for the control of scale. It is very essential to be thorough in its application, covering every part of the twigs, branches and trunk.

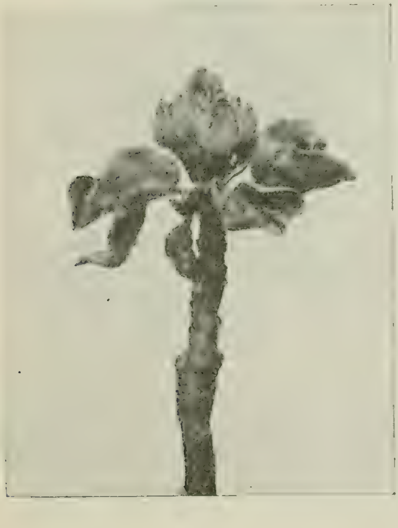

Fig. 1. Cluster buds at the "pre-pink" stage. This shows the stage of bud development at which the "pre-pink" spray should be applied.

SUMMER SPRAYS.

A pre-pink spray,—is recommended for all varieties very susceptible to scab, being applied just as the blossom buds have begun to separate in the cluster, to control the primary infection of scab.

For this spray use bordeaux-mixture or lime-sulphur (1¼-50).

A pink spray.—should be applied to all varieties of apples as soon as the blossom-buds separate in the cluster, to prevent scab and other diseases and to kill canker-worm, bud-moth and other pests. Use the same materials in the same proportions, as in the previous spray with one to one and one-half pounds of arsenate of lead powder, adding ½ pint of 40 per cent nicotine-sulphate solution to each 50 gallons when plant-lice or red-bug are believed to be present.

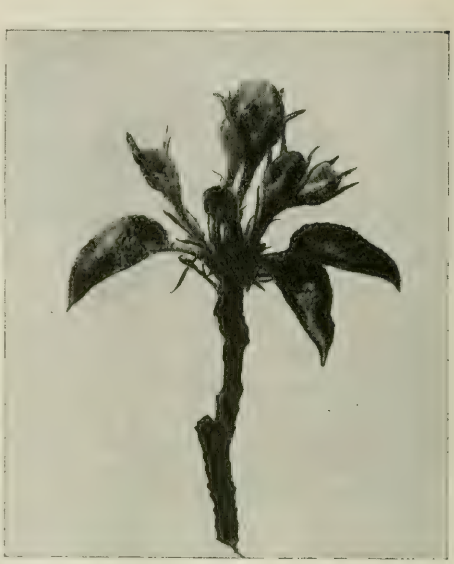

Fig. 2. Cluster buds at the "pink" stage. This shows the stage of bud development at which the "pink" spray should be applied.

A calyx spray,—should be applied after the blossoms fall and before the calyces close, using lime-sulphur solution with arsenate of lead as in the previous sprays, to which 40 per cent nicotine-sulphate may be added if plant-lice or red-bug still persist. This is an important spray for the control of the codling-moth as well as for scab and other troubles. The use of bordeaux-mixture is not advised at this time.

Two weeks after the calyx spray,—another application should be made using lime-sulphur solution with arsenate of lead as before.

Some growers apply another spray the same as the above, but using either bordeaux or lime-sulphur with the arsenate of lead about the first of July. This undoubtedly helps considerably in the control of scab in moist seasons and of codling-moth at all times.

The young of the second generation of codling-moth commence to enter the fruit during the latter part of July or early in August, the exact time varying considerably with the season. To care for the larvae of this second generation one may apply a spray of dilute lime-sulphur or bordeaux and arsenate of lead during the first week of August or better still two sprays, one the latter part of July and the other during the second week of August; or one may apply such a spray on the date determined by the emergence of the adult winged moths of the first generation. To determine this date one must cage a quantity of the first wormy apples in early June or late May and watch for the moths, allowing one week after the moths emerge in numbers for the eggs to be laid and the larvae to commence operations. The Department of Entomology has been attempting for several years to maintain cages at observing stations in various parts of the State and to set the date for this spray for each county annually, through the agency of the county agricultural agents. From the very nature of the case the date can not be set until very close to the time of spraying because it is determined by the emergence of the adult moths.

The lesser apple-worm,—works more superficially than the codling-moth. Sometimes it merely mines under the skin. It resembles the codling-moth in many ways, but is smaller. When present it requires a spray of poison, to be applied when the standard winter varieties are from 1½ to 2 inches in diameter. This spraying should be thoroughly done. It may take the place of the second application after the petals fall or an additional spraying may be made. The other regular sprays will also help to keep the Lesser Apple-worm in check.

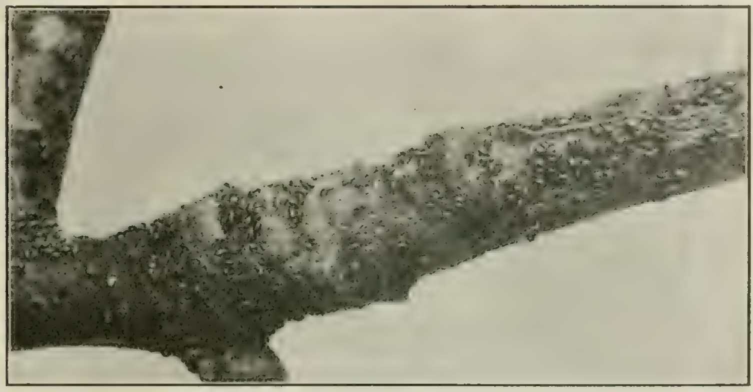

Fig. 3. Eggs of plant-lice on apple-twigs.

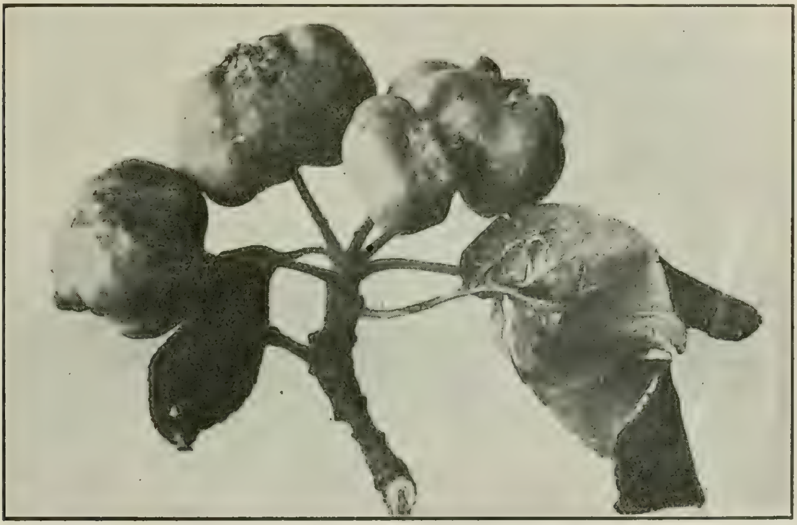

Fig. 4. Apples stunted and deformed by rosy-lice and green-lice.

Plant lice,—of several kinds infest the apple tree, but their effect on the fruit depends largely on weather conditions. The *red-bug* is also now well distributed over the State. The eggs of both these insects are hatched out by the time the buds turn pink, and *at that time* the plant-lice are easily killed and the adults of the red-bug are unable to fly. If either the rosy-louse or the red-bug is strongly suspected of being present, apply a spray of nicotine-sulphate, using a pint of 40 per cent nicotine-sulphate, to 100 gallons of water, adding 2 or 3 pounds of soap to the mixture; or else add a pint of the 40 per cent nicotine-sulphate to 100 gallons of bordeaux or dilute lime-sulphur. Stir the nicotine in just before applying, and be sure to omit the soap in this latter case. An early spring with warm, dry weather following is unfavorable to the lice, and a cold, wet, late spring is favorable to the lice. In seasons such as the latter, spraying is almost imperative. As both of these insects feed by sucking the sap from the foliage and from the fruit, it is necessary to use a contact spray. The safest contact spray, besides being the only one that can be mixed with lime-sulphur or bordeaux, is nicotine-sulphate.

Fire blight,—Fire blight is sometimes a serious disease in apple trees. A constant watch should be kept for its appearance from the time the trees blossom until the end of the growing season. For a description and method of control see "Treatment for Pears."

If dusts are used,—in place of liquid sprays, they should be applied at the following times;—a pre-pink application, a pink application, a calyx application, one two weeks later, one about the first of July, one about the first of August or late in July, and one about two weeks later. If weather conditions are particularly dry, some of these may be omitted but the pre-pink application, the pink application, the calyx application and the one applied about the first of August should never be omitted, regardless of weather conditions.

SPRAYING PEACH ORCHARDS.

Dormant Sprays. The dormant spray should be applied to peach trees when scale insects are present on the trees. Careful inspection should be made to ascertain whether or not they are to be found. Peach leaf-curl is a most common and serious disease of peaches in Michigan and is especially serious on Elberta. If scale is present a strong dormant spray of lime-sulphur solution (6¼-50) should be applied just *before the buds swell and the bud scales loosen,* which will destroy the scale and also prevent leaf-curl. If the scale is not found the spray should be applied for leaf-curl just before the buds swell and the bud scales loosen, using 2½ gallons of lime-sulphur with enough water to make 50 gallons. This spray in extensive orchards and in the absence of scale may be applied earlier to facilitate the work. Fall or winter applications for leaf-curl are generally efficient. The control of this disease is not usually efficient if the spraying is not done before the buds begin to swell. Scale, however, demands that the spray be put on *just before* the buds swell.*

Summer Sprays. The summer spraying of peach orchards may be a very profitable practice in preventing decayed, scabby and wormy fruit. The brown-rot usually appears just before harvest and may develop in the package after shipping. Scab seriously detracts from the appearance of the fruit and the work of the curculio produces blemishes; also these spots often serve as points of entrance for the fungus of brown-rot. Spraying also increases the bright and desirable color, so much so that some progressive growers find it "pays to spray for color."

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*See tables for dilutions for this and other lime-sulphur sprays on back cover.

Peaches should never be heavily summer sprayed because of their susceptibility to foliage injury. The above troubles commonly found in Michigan peach orchards may best be controlled by the following sprays:—

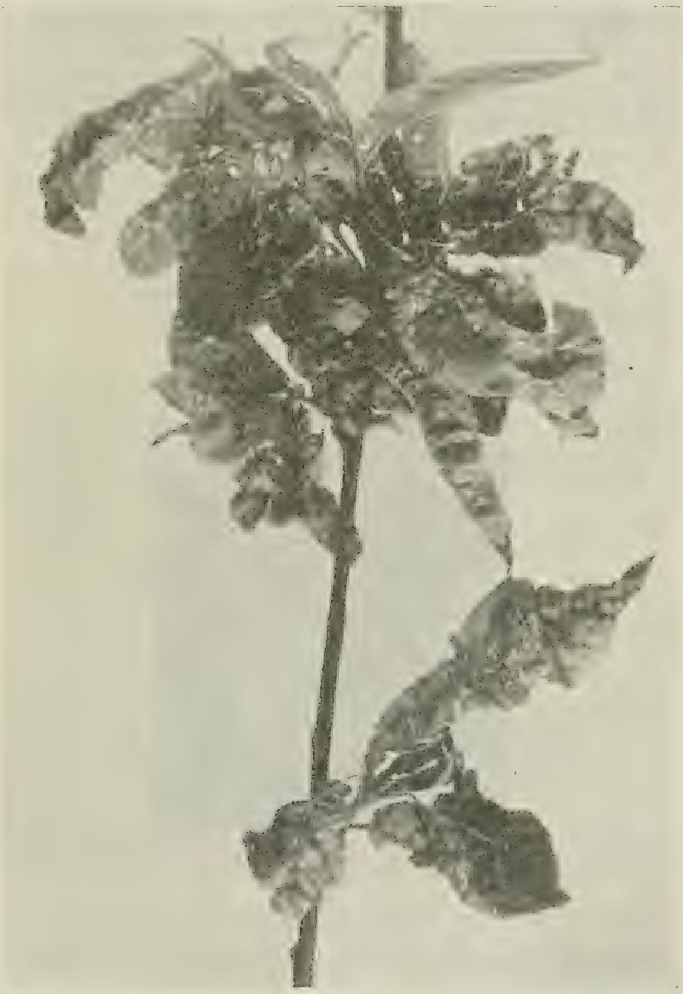

Fig. 5. Peach leaf-curl. This disease is controlled by a dormant spray.

After the blossoms drop and most of the "shucks" have fallen, apply a spray using one pound of arsenate of lead powder with two or three pounds of lime (to prevent foliage burning), in 50 gallons of water. If curculio is not present or serious, this spray may be omitted.

About two weeks after the "shucks" have fallen, apply a spray of self-boiled lime-sulphur to every 50 gallons of which add 1 pound of arsenate of lead powder. Self-boiled lime-sulphur settles rapidly so it should be kept well agitated and the poison should not be added until just before applying. This application is to prevent brown-rot, scab, and the curculio.

About one month before the fruit ripens, spray once more as directed above.

Recent experiments by the Horticultural Department have demonstrated the efficiency of the sulphur dust applied ten days to two weeks before harvest to prevent the development of brown-rot during the ripening period or directly after, while the fruit is in transit, and before it reaches the consumer. (For further details see Experiment Station Special Bulletin No. 115).

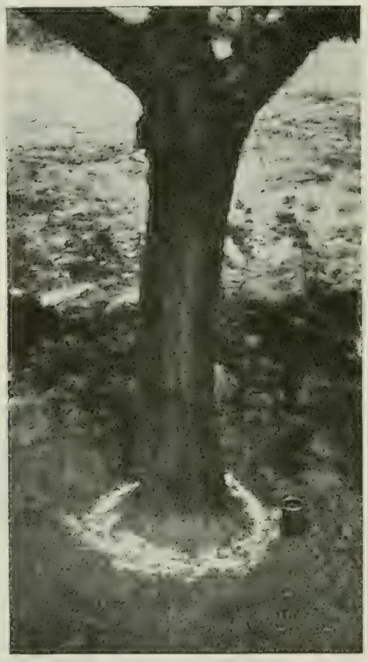

Fig. 6. First step in treatment of peach-borer with paradichlorobenzene. The tin cup holds just an ounce.

PEACH TREE BORER.

Dig out by hand early in the spring or late in the fall at points where the gumming shows. Sterilize the knife with 2 to 5 per cent compound solution of cresol after finishing with each tree, in order to prevent the spreading of crown-gall which is often present. In order to facilitate the removal of the larvae of "worms" many growers practice MOUNDING OR DITCHING. It seems to be of advantage to change the level of the soil around the base of the tree, either raising the level by making a mound of which the tree is the center, or lowering the level by digging away the soil in June and allowing the soil to be worked back by cultivation. Undoubtedly it is easier to pull away the mound to expose the injured crown than to dig out the soil. The mound is later replaced after the wounds have dried. On the other hand, most growers that do not mound, do leave the soil out of the pit around the base of the tree in "worming" until it fills during the summer, thus allowing time for the sun to dry the wounds and toughen the surface. There is also present in Michigan the Lesser Peach-borer, which works more in the body and limbs, and the upper part of the tree.

Paradichlorobenzene is a solid crystalline substance, the use of which, in this connection bids fair to supercede the practice of "worming" peach trees just described. Recent experiments seem to show that it will kill borers in the crown and roots which lie below the line of the application, without injury to the tree. Undoubtedly extensive use of this comparatively new method will develop new kinks and make its use more safe to the tree. Thus far its use seems to be restricted to trees of six years or older.

The dose usually applied is ¾ ounce or 1 ounce to a tree, the crystals being fairly fine and all lumps crushed and screened. Prepare the tree by clearing away weeds, grass, leaves, etc., from about the base of the trunk, clearing a space but not loosening the soil, and distribute the crystals in a narrow band one inch wide and two inches from the trunk of the tree. Then place several shovelfuls of soil about the tree over the crystals, so as not to disturb them. The best time to apply seems to be the last week of August or the first week of September and the soil should be left undisturbed for three or four weeks after which it should be pulled away from the tree, in order to avoid an over-dose. More detailed directions will be furnished on request by the Department of Entomology.

PEACH YELLOWS.

This is a very infectious disease the cause of which is unknown. The first symptoms in a young tree, previous to bearing, are indicated by the leaves of one or two limbs turning from a rich dark green to a "yellowish-green or reddish-rusty-green" color; this is accompanied by a rolling of the leaves from their edges. These leaves ripen and fall earlier than normal leaves. The fruit-buds are larger and more mature in appearance and in the spring will invariably bloom earlier than healthy buds. In some instances, the symptoms are not confined to one or two branches, but many of the leaves in the center of the tree turn yellowish or light-green, roll slightly at their edges and droop considerably. These latter symptoms are often present in case of "Little Peach."

Upon bearing trees, there may be any one or all of the following symptoms: The fruit may ripen prematurely—one to three weeks—upon one or two branches or over the entire tree. The fruit may have numerous red spots on the surface, the spots sometimes extending in red streaks partially or wholly through the flesh to the pit. Often the flesh, about the pit is full of radiating streaks of red. The surface of the fruit may be smooth or considerably roughened and the flesh more or less stringy and very insipid. The leaves may be yellowish, pale or reddish rusty-green in color, usually rolling and drooping. In advanced stages, numerous finely branched shoots bearing many slender, sickly leaves, appear on the trunk or main limbs and sometimes near the ends of the branches. Finally the tree dies.

Winter injury to the bark of the trunk or main limbs, mechanical injury by mice, rabbits, peach-borers, cultivators, etc., or a serious lack of moisture or nitrogen in the soil may discolor the foliage and cause premature ripening of fruit and should not be mistaken for "Yellows."

The only method of control is by the destruction of an infected tree,—fruit, root and branch—just as soon as discovered. It is especially important that diseased trees should not be allowed to blossom, as it is believed that the disease is spread by insects at that time.

LITTLE PEACH.

In "Little Peach," characteristic symptoms are:—the leaves of a part or the whole of the tree have a bunched appearance, and are shorter, and broader than normal leaves. They are usually yellowish-green in color with veins appearing dilated and darker than the intervening tissue.. The fruit is usually under size and ripens from a week to two weeks late. The flesh is more or less stringy, watery and very insipid, while the pit is usually very small. One or all symptoms may be present and unless they can be positively attributed to some other cause, the tree should be condemned, pulled out and burned.

Spraying Pear Orchards.

Dormant Spray. *In the fall, winter or early spring,* inspect for scale-insects the same as in apple orchards, and if found, spray as is directed for apple orchards. (See page 405.)

A spraying for scale will also control the Pear blister-mite, (a mite that causes thickened red spots which later become brown on the leaves and fruit). This creature has been a serious pest in parts of Michigan for the past few years.

A Delayed Dormant Spray. In orchards infested with *pear psylla* the dormant spray may be delayed until the blossom-buds are just showing white, and beginning to separate from each other in the cluster, using lime-sulphur solution (6¼ to 50). Some foliage burning may result but not enough to offset the beneficial effects of this spray. Kiefers are apt to be a little ahead of the other varieties. During the season of 1921 this spray directed against the eggs of the pear psylla proved very effective and it may in time supersede the older practice of using nicotine while the tree is dormant.

Summer Sprays. *Just as the blossom buds are showing white* and before they have separated in the cluster, a spray should be applied to prevent scab, especially on varieties susceptible to scab. For this application bordeaux mixture or lime-sulphur (1-50) may be used, to which add 1 to 1½ pounds of arsenate of lead powder for each 50 gallons. The delayed dormant spray for pear psylla will take the place of this spray. Primary infection of scab occurs some seasons before the succeeding spray.

When the blossom buds have separated in the flower cluster,—spray with lime-sulphur (1-50) or bordeaux, adding 1½ pounds of powdered arsenate of lead to each 50 gallons.

Immediately after the petals fall,—a spray should be applied, using bordeaux-mixture to which 1½ pounds of arsenate of lead powder should be added for each 50 gallons. Add nicotine-sulphate (1 pint to 100 gallons) if pear psylla is still present. (Lime-sulphur used at this time or with the succeeding spray is quite apt to injure the foliage).

Two weeks later apply another spray of bordeaux to which add 1½ pounds arsenate of lead powder to each 50 gallons.

THE PEAR PSYLLA.

The Pear Psylla is a serious and important insect regarding which pear growers must be fully informed. It passes the winter in rubbish, such as prunings left in or near the orchard, on the trunks of the trees, in the cracks and crannies of the rough bark, and on the twigs among the buds. It may be controlled by the following thorough treatment.

1. Late in the fall, November or December, scrape the loose bark from the trunks and large limbs and gather and burn or bury. Do not leave on the ground.

2. On a bright and fairly warm late fall day the insects will come out of their hiding places and can then be killed with a contact spray. Use some 40 per cent nicotine-sulphate solution at the rate of 1 pint in 100 gallons of water and to make it spread easily and quickly and so go farther, add 3 pounds of dissolved soap. Any cheap soap will do. Spray both sides of each tree,—the insects are lively and will dodge the spray. The best possible job can be done by spraying both sides of each tree at the same time, or at least by completing the job before any one part of the sprayed trunk or limbs becomes dry. It is hoped that the delayed dormant spray noted above will supercede this winter nicotine spray and if the latter continues to show up as well as in 1921, it will do so.

FIRE BLIGHT.

Fire blight is a bacterial disease of pears, apples, quinces and plums. It attacks blossoms,—causing "blossom blight"; twigs,—causing "twig blight"; limbs,—causing "limb canker"; and trunks of trees,—causing "body blight" and "collar blight." It characteristically works rapidly in the cambium and bark, killing so quickly that the leaves cling to the twigs, making the tree look as if scorched by fire.

The common varieties of pear, except Kiefer,—all varieties of quince,—Tolman sweet, Jonathan, Transparent, Chenango apples,—Transcendent and other crab varieties,—are especially susceptible. It it a disease which does serious damage to young, rapidly growing trees. Old trees and trees in sod, making slow growth, suffer less from blight. Serious loss has come from "blossom blight" on Duchess, and from collar blight with varieties on susceptible stocks (French crab).

Spraying is not a preventive for this disease. Control measures consist, (1),—in elimination of the hold-over cankers, (2),—in the prompt, and consistent cutting out of blighted twigs in the orchard.

The hold-over cankers arise from the blighted twigs of the previous year and can be located readily in the winter.

Pruning should be severe and each cut should be disinfected with either formaldehyde 1-10 or with a 5 per cent wash of compound solution of cresol or any standard coal-tar preparation of the sort. Prunings should be collected and burned.

In the growing season, especially in June and July, make frequent and thorough inspections of the orchard and cut out all twig-blight cutting back for a considerable distance, leaving no stubs and disinfecting each pruning cut. Such prunings should be collected and burned.

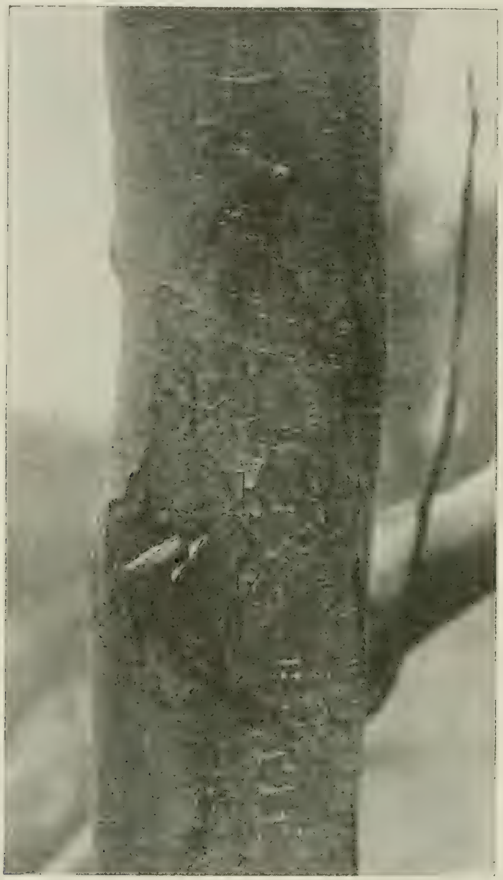

Fig. 7. Hold-over canker of fire blight. Such cankers should be cut out to remove source of early spring infections.

With young orchards, fire-blight control must not be neglected. Old trees frequently show a discouraging amount of fire-blight, which, however, usually does not cause serious damage. Mature trees in sod, properly fertilized, making a satisfactory growth seldom are injured seriously by blight.

When slugs appear,—spray with an arsenical, if not too near picking time of fruit to be dangerous. In case of early pears, fresh hydrated lime may be heavily dusted on.

Spraying Plum Orchards.

Dormant Sprays. Plum trees may be attacked by the San Jose or European fruit scale. If found, spray before growth starts with strong lime-sulphur or other efficient scale destroyer, the same as directed for apple orchards.

Just before the flower buds open,—spray with dilute lime-sulphur or the bordeaux-mixture and to every 50 gallons add 1½ pounds of arsenate of lead powder. (On Japanese varieties always use self-boiled lime-sulphur.) This is to prevent leaf-spot, brown-rot, black-knot, and curculio.

Immediately after the blossoms fall,—it is very essential to spray to prevent leaf diseases, brown-rot, and curculio. Use dilute lime-sulphur or bordeaux-mixture. For each 50 gallons of whatever is used, add 1 pound of arsenate of lead powder.

This is an important spraying. Be on time and be thorough.

Ten days or two weeks later,—it may pay to repeat the previous spraying, especially if the weather is wet or the curculio serious. With varieties that are susceptible to the brown-rot, it may pay to make sprayings every ten days or two weeks until there is danger of staining the fruit; stopping at least a month before picking time. If desirable to make later applications use a sulphur dust or a spray of weak copper-sulphate,—one pound of copper-sulphate to 150 or 200 gallons of water. Poison need not be used.

Black Knot. Early in the spring a careful inspection should be made of every tree, and all "black-knots" cut out and destroyed. Cut back several inches below the knot. Disinfecting cuts as for pear-blight is not necessary. Wild cherry trees harbor the disease and if diseased ones are near plum or cherry orchards, the wild trees should be destroyed, if possible.

Sulphur Dusts. Recent experiments made by the Horticultural department have demonstrated the efficiency of lime-sulphur dust of 90 per cent sulphur and 10 per cent hydrated lime, applied ten days or two weeks before picking, for the control of brown-rot after harvesting. (See Michigan bulletin No. 115 for further details.)

SPRAYING CHERRY ORCHARDS.

Inspect sweet cherry trees for scale and if found spray as for apple orchards. Sour cherries are not commonly troubled by the San Jose scale; therefore it is seldom necessary to spray them with strong lime-sulphur.

Just before the blossoms open,—spray with dilute lime-sulphur (1½ to 50) or bordeaux-mixture to prevent leaf-spot and brown-rot. The application of this spray at this time is especially advisable with English Morellos and in orchards infested with leaf-spot the previous season.

Just after the blossoms fall,—spray with dilute lime-sulphur (1½ to 50) or bordeaux-mixture, to every 50 gallons of which add one pound of arsenate of lead powder. This application is to prevent leaf-spot, brown-rot, curculio and slugs.

Ten days or two weeks after the above spraying,—it is necessary to make another application of the same mixture.

Another application as above should be made about July first especially if weather conditions have been favorable for the development of leaf-spot. Also, an application should be made directly after harvesting as an infection period for leaf-spot may come any time during the remainder of the growing season if weather conditions are favorable.

Large Black Lice,—may appear on the leaves at any time. A spray of nicotine sulphate—one pint to one hundred gallons of water with 3 or 4 pounds of soap will destroy them.

Cherry Fruit-Fly. Two sorts of small white maggots are often found in ripening cherries. These footless maggots are the larvae of cherry fruit-flies. The only way to successfully combat these fruit-flies is to lightly spray or sprinkle the trees with arsenate of lead when the flies are preparing to lay their eggs in the immature fruit in early June. Use a mixture containing 2 pounds of the powder to 100 gallons of water.

GRAPES.

Grape vines are seldom attacked by scale insects, therefore there is seldom need of a dormant spray of lime-sulphur. Dilute lime-sulphur should not be used for summer spraying of grapes. Bordeaux is the standard spray for fungous troubles combined with arsenate of lead to control chewing insects.

Summer Spray. Black-rot is a most common and serious disease while downy-mildew is sometimes very destructive. These diseases and others may be controlled by spraying as follows:

When the shoots are eight to ten inches long,—spray with bordeaux-mixture for black-rot and downy-mildew.

Just before blossoming,—spray again with bordeaux-mixture for black-rot and downy-mildew, and to every 50 gallons of bordeaux add one quart of Kedzie mixture or 1 to 1½ pounds of arsenate of lead powder to poison the grape berry-moth and the rose-chafer. If the latter is serious, the amount of arsenate of lead powder may be increased to as much as 2½ pounds to 50 gallons. A pint of the cheapest molasses added may help.

Just as the blossoms are falling,—make another spraying like the above. *From ten days to two weeks later,* another application may be desirable if weather conditions are favorable for the development of rot and mildew, or if the grape-berry moth persists, using the same materials as with the previous spray. If late applications are thought to be necessary, some material should be used that will not stain the fruit, such as weak copper-sulphate solution. (See page 423.)

There are several grape insects that are found only in occasional vineyards, and then not every year. The grower should keep a sharp watch of his vines for them, and if found, take prompt measures to destroy them. (If not familiar with their appearance send specimens to the Entomologist, East Lansing, Michigan.)

Those most likely to be found are the following:

Flea-beetles,—may appear at any time, but are most likely to come as the buds open in early spring. Spray with bordeaux-mixture and a strong poison, one quart of Kedzie mixture, or 1½ pounds of arsenate of lead powder, to every 50 gallons of the bordeaux, if early in the spring. Later use less poison.

In vineyards where the *grape-berry* moth is present, apply bordeaux (4-4-50 to which add Kedzie mixture, one quart to 50 gallons* or 1½ pounds or even more of powdered arsenate of lead to each 50 gallons of the bordeaux, just as the *very first* webs are spun, about three to five days after blooming nicely starts and again in ten days if necessary, and once more just before the grape berries touch in the cluster, so that a spray may still be forced in between the separate berries.

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*See directions for preparing insecticides, page 431.

The Kedzie mixture seems preferable to arsenate of lead for the control of berry moth.

For leaf-hoppers,—sometimes incorrectly called "Thrips," use nicotine-sulphate and bordeaux, at the rate of one pint of the nicotine to 100 gallons of bordeaux and apply just before the first nymphs change to the winged stage. Unfortunately the eggs, which are laid in the tissue of the underside of the leaves, do not all hatch at once and it is desirable to wait until the last moment in order to let as many as possible of the eggs hatch, some time between mid June and mid July. It may even be necessary to repeat this spray if the young wingless nymphs continue to appear. Success will depend on the thoroughness of application since each insect must be directly hit to be killed.

These insects winter under rubbish, *often at a distance from the vines* and the destruction by fire of all fallen leaves and other rubbish will prove a very important factor in the control of the pest.

For Climbing Cut-worms,—use tree tanglefoot on the vines, posts and wires. Also sprinkle poison bran bait near the bases of the vines. (See page 427.)

CURRANTS AND GOOSEBERRIES.

San Jose and European fruit-scale are found on currants although seldom on gooseberries. Inspect carefully for them and if found, spray before growth starts with lime-sulphur (6¼ to 50).

Summer Sprays. Just as the leaves are expanding, spray with bordeaux to which add one pound of arsenate of lead powder to every 50 gallons. (Recent experiments of this Station have demonstrated that lime-sulphur is not as efficient in controlling the fungous troubles on currants and gooseberries as bordeaux).

Repeat the above spray when the fruit is about one-fourth grown.

If "worms" trouble the foliage or fruit after this time and before the fruit is harvested, use hellebore.

Leaf bugs and aphids,—may appear, either one or both together. When they do, spray with nicotine-sulphate while the bugs are red and wingless and before the leaves have become curled. Spray upward from beneath.

Gooseberry mildew,—is a fungous disease that is especially troublesome on such English varieties as Industry, Columbus and Chautauqua. Spray with bordeaux. Begin when the buds start and repeat every 10 days to two weeks until near picking time.

When pruning,—if a cane shows discolored pith when cut, it may indicate the cane-borer. Cut back to sound pith. Burn trimmings immediately.

Wilted foliage,—at any time may indicate the cane-borer. Cut out and burn.

RASPBERRIES, BLACKBERRIES AND DEWBERRIES.

Red raspberries, especially Cuthbert and Marlboro, frequently show curled, distorted or mottled foliage. These are the signs of leaf-curl and mosaic. Such plants are diseased and are a menace to other plants in the plantation. They should be dug up with all their roots and suckers and burned. Such diseased plants should be dug out in the early half of the season to prevent spread of the disease by insects (aphids). New plantations should be set only from shoots of healthy plants.

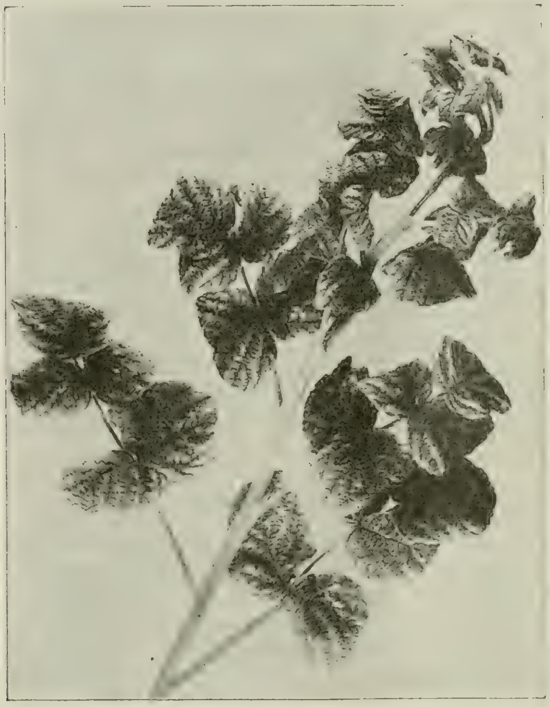

Fig. 8. Raspberry curl. Plants affected with this disease should be removed and burned.

A similar disease of black raspberries in which the nodes are shortened, the leaves curled and distorted, has destroyed many plantations. Eliminate all suspicious plants and use for new plantings only stock from healthy sources.

Crown gall, which shows up as a swollen, distorted knot on canes and crowns is very serious on raspberries and blackberries and diseased stock should never be used.

Anthracnose,—a common and troublesome disease especially of black raspberries and blackberries, identified by the grayish spots generally near the bases of the canes. Recent spraying experiments prove the necessity of three applications of lime-sulphur solution to control it, applied—first,—in early spring just before growth begins, using 2½ gallons testing 33° Beaume, to 50 of water; second,—when the new canes are six to eight inches long, using 1 gallon to 50; third,—just before blossoming, at the same rate as previous spray. The removal of all grass, weeds and trash in the plant rows, keeping them clean and well cultivated, will help to prevent this disease.

Orange Rust may appear in May or June. It is easily identified by the bright orange color on the under sides of the leaves. There is no method of preventing this trouble. As soon as it is found, the bush should be dug out and burned. If allowed to remain the disease will spread and destroy many plants. Secure disease free plants in starting new plantations.

"Worms" or "Slugs",—may appear at any time. Spray with an arsenical if early in the season, but if near picking time, use hellebore or pyrethrum.

Cut out and burn gouty galls, tree-cricket eggs and borers in stems.

STRAWBERRIES.

Examine the young plants before setting them. Pick off all discolored or diseased leaves. If root-lice are suspected dip the root in strong nicotine solution.

After the growth starts, spray with bordeaux and an arsenical poison to prevent the leaf-spot, and to destroy the leaf-roller insect that may be present.

For fruiting plantations, spray with bordeaux before blossoming, and repeat ten days to two weeks later after blossoming. After fruiting, if the bed is to be fruited again, mow and burn over quickly (as on a day when there is a wind, to avoid burning the crowns of the plants). If *Leaf-Rollers* have been present in the immediate past, spray with poison aftr the growth has started again, but before the leaves curl.

For Strawberry Root-Louse,— be sure to set out clean plants, dipping the roots in a wash of nicotine-sulphate when necessary, using one pint to 100 gallons of soapy water and setting on land which was under intensive cultivation when possible in order to avoid the presence of ants in the soil.

POTATOES.

For the Blight and "Bugs,"—begin spraying with bordeaux-mixture and poison when the "bugs" first appear, or when the plants are about eight inches high, and repeat about every two weeks as long as the plants are growing. Spray often in warm, muggy weather; fewer sprayings are necessary in dry weather.

Use bordeaux-mixture (4 pounds copper-sulphate and 4 pounds of unslaked lime or 6 pounds of hydrated lime to 50 gallons of water), and put in poison,—about 1 pound of the powdered arsenate of calcium. or 1 quart of the stock solution of Kedzie-mixture. This amount of Kedzie-mixture is equivalent to ½ pound of Paris-green. Some growers prefer to use even more than this. Arsenate of lead at the rate of 2 pounds to 50 gallons of bordeaux is extensively used but it costs much more than either of the poisons noted.

Potato Aphis. During wet summers and especially during those that follow cold, wet springs, the potato-louse is apt to appear. This potato louse is not such a difficult insect to kill if one can only reach it with a spray. The difficulty comes from the fact that it hides under the foliage of the potato, and that the spray must be directed upward from beneath in order to hit any large proportion of the lice. Several devices have been made for bringing about this result. The spray most efficient is the ordinary 40 per cent nicotine-sulphate, used at the rate of 1 pint to 100 gallons of water with 3 or 4 pounds of laundry soap added. When expedient one may use the nicotine-sulphate in bordeaux (without soap).

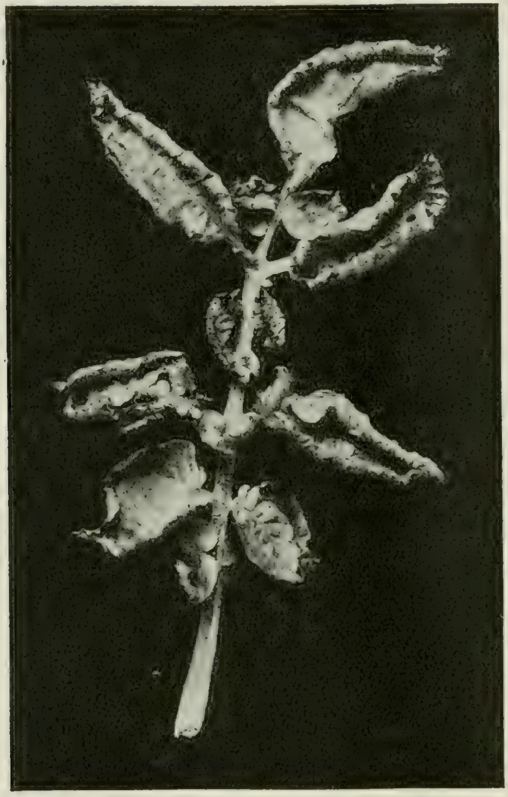

Fig. 9. Potato leaf showing hopper-burn.

The Gray Field-Slug,—(*Limax agrestis*) of Europe has finally become established in Michigan. It is a snail, less than ¾ inch long, without a shell, and it flourishes in moist places, feeding mostly at night on lettuce, celery, potatoes (the tubers) and other vegetables. Poison bran bait is the best that can be done for it at this time. Scatter the bait in the vicinity of plants to be protected. (The Giant Slug is also present in Michigan but has not become widespread as yet).

Potato Leaf-Hopper,—the tiny, active leaf-hopper of potatoes is the cause of hopper-burn, also known as tip-burn. This insect is easily killed, before it gets its wings, when hit by a spray of nicotine-sulphate but in our fields adult winged individuals are constantly coming in,—just about as fast as we can kill them—we have no entirely satisfactory repellant but probably the best that we have is bordeaux. *A coat of* *bordeaux-mixture on both the upper and lower surfaces of the leaves is really the best protection to be had at present.* It acts as a repellant but does not cause the death of the hoppers. The spray should be applied upon the first appearance of the hoppers and continued at intervals as long as they remain, with the addition of arsenate of calcium or of Kedzie-mixture for flea-beetles and the Colorado potato-beetle.

TOMATOES.

Leaf Blight,—this disease can be prevented by the proper use of bordeaux. The standard 4-4-50 formula is the strength most commonly used. The first application should be made while the plants are in the seed-bed or cold-frame. The second spraying should be made soon after the plants are set in the field. This should be followed by additional sprayings every ten days or two weeks until the fruit begins to ripen. During wet seasons more and later sprayings are necessary than when the weather is comparatively dry.

Flea-Beetles,—small, black flea-beetles sometimes appear and eat pits in the foliage of the tomato plant. The easiest way to control them is to spray with bordeaux-mixture and arsenate of lead in the ordinary way. Such sprays, of course, must not be continued after the fruit begins to get very large.

Tomato Worms, the large green "worms" that devour the leaves of the tomato plants can be controlled when the worms are small by a spray of arsenate of lead applied in the ordinary way.

MUSKMELONS AND CUCUMBERS.

Several insects interfere with the welfare of cucumber and melon vines. **The Cucumber Beetle** (striped) feeds on the leaves, and the young tunnel as grubs in the roots. Plant more seeds than are needed to produce vines and thin out the injured plants; also dust with hydrated lime and flour of sulphur (one of sulphur to five or six of lime), through coarse cloth. Some prefer turpentine, 2 or 3 tablespoonfuls to a 12-quart pail of hydrated lime.

The Cucumber Louse,—usually starts in a few hills and then spreads over the field,—cold, wet weather being favorable to the louse. Some prefer to bury the first few vines attacked to retard spreading. A good spray is Persian insect powder, ½ ounce to a gallon of water; also nicotine-sulphate, ½ pint to 50 gallons of water, if 40 per cent sulphate is used, spraying upward from beneath. The difficulty lies in getting the spray on to the lice. Each louse must be fairly hit to be killed.

The Large Black Squash-Bug,—or stink-bug, not only feeds on vines, but probably also carries the wilt. It may be trapped on cold nights under pieces of board and dropped into a can of water, having a little kerosene on top.

PREPARATION OF SPRAY MIXTURES.

Commercial Lime-Sulphur. Commercial lime-sulphur solution is now very generally used by Michigan fruit growers. A few growers, however, find it desirable to make their own concentrated lime-sulphur solution although most growers feel that the convenience of obtaining the commercial concentrated solution outweighs the advantage of the homemade product. Those desiring to make their own concentrated lime-sulphur solution may obtain detailed directions by writing to the Entomological Department.

The Agricultural Laws of Michigan require the manufacturer to state plainly on each package of spray material "the correct names and percentage amounts of each and every ingredient of the insecticide or fungicide having insecticidal or fungicidal properties and the total percentage of inert ingredients present."

The "strength" or "Beaume Test" in concentrated lime-sulphur may be known from the "Total per cent Sulphur" given on the label of the commercial manufacturer.

When Total Percent Sulphur is 26, Beaume Test is 33.
When Total Percent Sulphur is 25, Beaume Test is 32.
When Total Percent Sulphur is 24, Beaume Test is 31.
When Total Percent Sulphur is 23, Beaume Test is 30.
When Total Percent Sulphur is 22, Beaume Test is 29.
When Total Percent Sulphur is 21, Beaume Test is 28.

A Beaume hydrometer may be purchased from dealers in druggists' supplies.

SELF-BOILED LIME-SULPHUR MIXTURE.

This material is used particularly for summer sprays on tender foliage fruits such as peaches and Japanese plums. The formula is:

Lump lime	8 pounds
Sulphur	8 pounds
Water	50 gallons

The mixture can be prepared better by using 32 pounds of lime, 32 pounds of sulphur, and 8 or 10 gallons of water, and then diluting to 200 gallons.

Place the lime in a barrel and add enough water to almost cover it. As soon as vigorous slaking develops, sift in the sulphur stirring vigorously, or better still, add the sulphur which has previously been sifted and mixed with water into a thick paste, by adding slight amounts and stirring vigorously. Stir constantly and add enough water to make a thick paste and then, gradually, a thin paste. As soon as the slaking of the lime has vigorously boiled the sulphur for about five minutes, cold water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted up to the full formula and used.

Care must be taken not to allow the boiling to proceed too far,—if the mixture remains hot for fifteen or twenty minutes after the slaking is completed, too much sulphur will go into solution and injury to the foliage may result.

The time of adding the cold water to stop the boiling depends upon the lime. With a sluggish lime all the heat in it may be needed, while with the limes that become intensely hot, care must be taken not to allow the boiling to proceed too far.

BORDEAUX-MIXTURE.

Bordeaux-mixture is made of copper-sulphate, lime and water.

These three substances are combined in various proportions, depending upon the kind of plant to be treated. For apples, pears, cherries, grapes and plums (except Japanese varieties) the proportion is usually four pounds of copper-sulphate, with about the same amount of lump lime, (unslaked lime) to fifty gallons of water. When hydrated lime is used, use six pounds instead of four. Poison is added as needed. The copper-sulphate will readily dissolve in two gallons of hot water, to which should be added enough water to make 25 gallons, or one-half barrel. Do not use an iron or tin vessel to dissolve this in, as the copper-sulphate will destroy it, and besides, the iron will spoil the bordeaux. A wooden pail is good. Slake the lime into a thin paste and add water to make 25 gallons. Pour, or let these run together into a third barrel, and the bordeaux is made. When it is emptied into the spray barrel or tank, it should be strained through a brass wire strainer to catch any of the coarse particles.

Whenever it is necessary to use a quantity of the mixture, it is desirable to have the lime and copper-sulphate in "stock solutions." A quantity of lime is slaked to a paste and held so by being covered with water. The copper-sulphate, say 50 pounds, is placed in a clean gunny sack and suspended in a barrel (one with wooden hoops is much to be preferred) containing 25 gallons of water. This will dissolve in about a day. One gallon of this "stock solution"* is equal to two pounds of copper-sulphate.

A good quick way to combine these three substances is as follows:

Put the amount of the "stock solution" of copper-sulphate required in a barrel, and add enough water to make 25 gallons, or one-half barrel. Put about seven pounds of the lime paste in a barrel and add 25 gallons of water, making a thin whitewash. Pour, or let these two run together into a third barrel, or directly into the spray barrel or tank, being sure to strain. If arsenate of lead, or any other poison is to be used, make it into a thin paste with a little water and add it to the bordeaux-mixture, which is now ready to be used.

COPPER-SULPHATE SOLUTION.

Copper-sulphate solution is copper-sulphate dissolved in water. It is used by some growers to spray peaches, plums and grapes to prevent rot,—when it appears just before harvest. One pound of copper-sulphate to 100 to 200 gallons of water is used, depending upon the susceptibility of the foliage to spray injury.

Prepared Bordeaux. There are many brands of prepared bordeaux-mixtures upon the market, sold under various proprietary names. Some of them also contain arsenical poisons. Up to this time we have been convinced by experience that a freshly combined homemade bordeaux is superior to anything else in controlling fungous diseases.

STOMACH POISONS.

For Insects that Chew

ARSENATE OF LEAD.

This poison is used very extensively. The powdered form is most commonly handled at the present time and in the formulas of sprays recommended in this bulletin the amount of arsenate recommended is considered to be in the powdered form. When the paste form is used, twice the weight of the powder is required. When using arsenate of lead alone on stone-fruits, from three to five pounds of freshly slaked or of hydrated lime, to each 50 gallons of the spray, may be added to prevent foliage burning. Arsenate of lead may be mixed with lime-sulphur, bordeaux or any of the other common fungicides to make a combination spray.

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*Always stir this "stock solution" before dipping any out, in order that what is used may be full strength.

PARIS-GREEN AND LIME.

Never mix Paris-green with lime-sulphur in any form. Paris-green can, however, be used with bordeaux-mixture with safety.

For spraying from a barrel, the writer has found the following method very useful: Place from ½ to one pound of good lump lime, or unslaked lime, in each of three or four tin pails which will hold about three quarts or less. Old cans or crocks will answer just as well. Add enough hot water to slake it into a thin cream or paste. Now add to each lot ¼ pound of Paris-green, previously weighed out, and placed in a paper bag; stir in the Paris-green while the lime is hot and allow to stand for some time. Now measure out about 44 gallons of water in your spraying barrel, and make a mark that will show how high it comes in the barrel; add the contents of one tin pail (viz. ¼ pound of Paris-green and ½ pound of quick-lime slaked) into the 44 gallons of water in the barrel. Stir well and spray. The pails or crocks can be used one at a time and re-filled from time to time so that the stock is always on hand ready for use.

ARSENATE OF CALCIUM—KEDZIE MIXTURE.

This mixture, originated by the late Dr. R. C. Kedzie of this Station, is cheap, but it has the disadvantage of lacking a warning color. It must be made with care, and stored in well-labeled jugs. It is made of white arsenic (not arsenate of lead) and carbonate of soda.

Dr. Kedzie in giving directions for its preparation states:—"Dissolve the arsenic by boiling with carbonate of soda, and thus insure complete solution; which solution can be kept ready to make a spraying solution whenever needed. To make the material boil two pounds of white arsenic with eight (8) pounds of sal-soda (crystals of carbonate of soda—'washing soda'—found in every grocery and drug shop) in two gallons of water. Boil these materials in any iron pot not used for other purposes. Boil for fifteen minutes or until the arsenic dissolves, leaving only a small muddy sediment. Put this solution into a two-gallon jug and label, '*Poison,* stock material for spraying mixture'".

"The spraying mixture can be prepared whenever required, and in the quantity needed at the time by slaking two pounds of stone or lump lime,* adding this to forty gallons of water; pour into this a pint of the stock arsenic solution. Mix by stirring thoroughly, and the spraying mixture is ready for use. The arsenic in this mixture is equivalent to four ounces of Paris-green."

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*Three pounds of fresh hydrated lime may be made to take the place of the two pounds of stone or lump lime.

The jug, pot, etc., must never be used for any other purpose after using it for making this mixture."

If an additional pound or two of lime be added to the mixture it will help to make the application permanent and conspicuous without in any way interfering with its effect.

The final product obtained in the spraying tank is arsenite of calcium (not arsenate of calcium) which kills more quickly than arsenate of lead or arsenate of calcium. The formula given above was designed for spraying fruit trees but we are not at this time recommending its use for that purpose. When this poison is used for potatoes, use twice as much of the stock solution, or 1 quart to 40 gallons of water. Some potato growers prefer to use it even stronger than this.

ARSENATE OF CALCIUM.

This spraying material is sold in the form of a fine white powder. It normally costs a little less than arsenate of lead and goes about twice as far. We are not at present recommending its use on fruit trees because of a delayed burning effect that is apt to follow the application, but we do find it very satisfactory when used on potatoes which seem to stand it very well. It works more quickly than arsenate of lead and is more evenly distributed than Paris-green. Furthermore it is produced in a much finer powder than the last named poison and is less prone to drip off when applied in a coarse spray.

From ¾ of a pound to one pound may be used with bordeaux or freshly slacked lime to 50 gallons of water for potatoes and some growers use even a little more.

Contact Insecticides.

For Insects That Suck

NICOTINE.

The insecticide most generally used for the summer spraying of sucking insects, at the present time, is nicotine. Nicotine is a clear, colorless, odorless material when pure, although the commercial preparations contain impurities which impart both odors and color to the spray. It is marketed in two forms: the volatile, plain nicotine and the non-volatile nicotine-sulphate. For use in greenhouses and forcing houses, the volatile, plain nicotine is preferable because it disappears rather rapidly from the plants treated without leaving any deposit which would be dangerous or offensive. For out-door work, however, the sulphate is much to be preferred, since it is stable and does not evaporate and pass off into the air for a considerable length of time, at least. A favorite strength for marketing nicotine is 40 per cent, although some of the plain nicotines are put out at 10 per cent and some even stronger than 40 per cent. All references to nicotine made in this bulletin refer to the use of 40 per cent nicotine-sulphate since the bulletin deals with outside spraying and is not intended to include remedies for crops grown under glass or for vegetables such as lettuce, where the sprayed part is to be eaten soon after the application. Nicotine-sulphate may be stirred into the dilute lime-sulphur or arsenate of lead or a combination of the two immediately before the spray is applied. It should not be stirred in and allowed to stand before the application is made. In case nicotine is used in combination with any liquids other than water, soap should never be added. In case, however, nicotine is used by itself alone and diluted with water, soap adds greatly to its efficiency by causing it to spread better and perhaps in other ways. The favorite strength used in orchards and small fruit spraying is one part to 800, in other words, one pint to 100 gallons of water with three or four pounds of soap, or one pint to 100 gallons of dilute lime-sulphur without soap. Some growers dilute the nicotine still further, using one part to 1,000 of water or other spraying material. Of course, if one uses 10 per cent nicotine, one should use four times as much of it as if 40 per cent nicotine is employed, and any strengths of nicotine other than those mentioned should be diluted in proportion to their strengths.

KEROSENE EMULSION.

Place two gallons of ordinary kerosene in a warm place, either in a warm room or in the sun, and allow to become as warm as possible without danger from fire. Boil one pound of laundry soap or whale oil soap in a gallon of soft water until completely dissolved. Remove the soap solution from the fire, and while still boiling hot, add the kerosene and agitate vigorously for 10 minutes, or until the oil is emulsified, with a spraying pump by forcing the liquid back into the vessel from which it was pumped. When the liquid is perfectly emulsified, it will appear creamy in color and will flow evenly down the side of the vessel when allowed to do so. Care should be taken to completely emulsify the oil and this is accomplished much more easily when the mixture is hot.

This strong emulsion may now be readily diluted with water and used. If the water is at all hard, "break" it by adding a little sal-soda before putting in the soap.

Small amounts of this emulsion may be made by using the ingredients in small quantities, but in the same relative proportion. It is used at the rate of 8 or 10 parts of water to 1 part of emulsion.

HELLEBORE.

White hellebore is the powdered root of a plant. It kills both by contact and as an internal poison. It may be applied either dry or in the form of a liquid. When used dry it should be mixed with three or four times its weight of flour, hydrated-lime or of plaster and then dusted on the insects. Applied wet, one pound should be mixed with twenty-five gallons of water and this liquid applied as a spray.

INSECT POWDER, BUHACH, PYRETHRUM.

This valuable remedy has one drawback—its cost. It is too expensive for use on a large scale. It kills insects through their breathing pores, but is harmless to man and beast. It will kill many of the insects of the garden if dusted on or applied as a spray at the rate of one ounce to two gallons of water.

Use this powder when it is undesirable to use a permanent poison, but never buy any unless it comes in tightly sealed packages. It loses its strength on short exposure to the air. An hour will suffice to weaken it. It must be applied from time to time, as it quickly loses its strength.

HYDRATED LIME.

Fresh hydrated-lime is sometimes useful, because of its slight caustic properties. It is especially useful against such larvae of saw-flies and beetles as are sticky, as well as those of the cherry-slug and of the asparagus-beetle. The lime may be dusted on and used as a substitute for a poison if the latter for some reason is undesirable. This is not to be confused with ground quick-lime, which is used in making bordeaux-mixture, the latter being very caustic and likely to burn the foliage. Nor should hydrated-lime be confused with air-slaked lime, since the latter is not caustic at all. Hydrated-lime, when dusted on sticky larvae, clings to their bodies and attacks them through their skins.

Poison Bran (Kansas Bait).

This is especially useful for combating cut-worms. Sift together one pound of Paris-green or ¾ pound of white arsenic (not arsenate of lead) and 20 pounds of bran; add half a gallon of molasses or syrup and a little water and add a small quantity of ethyl acetate (acetic ether) or amyl acetate, which has the odor of bananas,—enough to distinctly scent the bait. This may be broadcasted over from two to five acres of land. It is very attractive to both cut-worms and to grasshoppers. Do not try to substitute any other poison for the Paris-green or white arsenic. Neither arsenate of lead nor arsenate of calcium will do the work unless large quantities of the poison are used. Neither should one use this bait where poultry are likely to pick up much of it, although the bait should be distributed in a finely broken up condition rather than in lumps.

CRIDDLE MIXTURE.

Criddle-mixture is horse-manure mixed with an arsenical, and slightly salted. It is to be distributed about the field in small masses, and is especially useful in combating grasshoppers, as it takes advantage of their well known love of salt. The proportions are as follows: Paris-green, one pound, or white arsenic, one pound; salt, two pounds; fresh horse-manure, 100 pounds or five three-gallon pailfuls. The salt is dissolved in a pail of water, the poison stirred in, and the whole mixed with the horse-manure in a half barrel.

SAWDUST—GRASSHOPPER BAIT.

Into a bushel of fresh hard-wood sawdust pour and *thoroughly mix* a mixture made as follows:—one gallon of water, one pound of white arsenic, (not arsenate of lead or calcium), a cup of molasses and one pound of salt. Add an ounce or so of either ethyl acetate or amyl acetate,—the former has the odor of pomace and the latter the odor of bananas, and either one is attractive to grasshoppers. Add enough water to produce a good stiff mash and broadcast. The ethyl acetate and amyl acetate are not absolutely necessary but they do make the bait attractive.

COMPOUND SOLUTION OF CRESOL.

For sterilizing knives, saws, shears and other tools, nothing is better than compound solution of cresol used at the rate of from two or five per cent in water. It has the advantage that it helps cleanse the tools and softens dirt that might otherwise cling to them. It is useful for cleansing and sterilizing tools used in pruning where diseases are present, and for sterilizing the knife used in cutting out peach-borers, in order to avoid distributing crown-gall through the orchard.

POISONED SYRUP FOR ONION MAGGOT.

Dissolve five grams or ¼ ounce of sodium arsenate in one gallon of hot water and add half a pint of New Orleans molasses. Distribute a small amount of this in small basins covered with wire screen of just small enough mesh to keep out bees, using 15 or 20 of these basins to the acre, and put the pans in position just as the onions begin to nicely get through the ground, keeping them replenished until the danger is past. The efficiency of this bait is increased if a slice of onion is added to the syrup in each pan.

Two tablespoonsful of the stock solution of Kedzie-mixture will take the place of the five grams of arsenate of soda.

CAUTIONS.

Do not spray while plants are in bloom. It is prohibited by law, except when canker-worm is present, and may destroy bees and other beneficial insects.

Do not dissolve copper-sulphate in an iron or tin vessel. It will ruin the vessel and spoil the spraying solution.

For all spraying solutions containing copper-sulphate, the pump must be brass or porcelain lined.

Wash out pump and entire outfit each time after using.

Use arsenate of lead with lime on stone fruits in preference to other forms of arsenical poisons. It is less liable to burn the foliage.

Do not spray fruits or plants with poison within a month of the time they are to be picked.

Keep all "stock solutions" covered to prevent evaporation, and oxidation. If a "spray gun" is used try to do the work when the mixture will dry on the tree quickly.

Do not use lime-sulphur solution as a summer spray for grapes, potatoes or tomatoes.

Do not use Paris-green or Kedzie-mixture in combination with lime-sulphur sprays.

TABLE OF DILUTIONS FOR CONCENTRATED LIME SULPHUR WASH

To spray for San Jose and other scale insects when plants are dormant or just before buds open in spring.		Summer spraying for apples and European plums.	
If Beaume test is	Amount below should be diluted to 50 gallons	If Beaume test is	Amount below should be diluted to 50 gallons
33	6¼ gallons	33, 32 or 31	1¼ gallons
32	6½ gallons	30, 29 or 28	1½ gallons
31	6¾ gallons	27, 26 or 25	1¾ gallons
30	7 gallons	24, 23 or 22	2 gallons
29	7½ gallons	21, 20 or 19	2¼ gallons
28	7¾ gallons		
27	8¼ gallons		
26	8¾ gallons		
25	9 gallons	Summer Spraying for Pears	
24	9½ gallons		
23	9¾ gallons		
22	10 gallons		
21	10½ gallons	33, 32 or 31	1 gallon
20	10¾ gallons	30, 29 or 28	1¼ gallons
19	11¼ gallons	27, 26 or 25	1½ gallons
18	11½ gallons	24, 23 or 22	1¾ gallons
17	12 gallons	21, 20 or 19	2 gallons
		Summer Spraying for Cherries	
		33, 32 or 31	1½ gallons
		30, 29 or 28	1¾ gallons
		27, 26 or 25	2 gallons
		24, 23 or 22	2¼ gallons
		21, 20 or 19	2½ gallons

DUSTING AND SPRAYING EXPERIMENTS OF

1920 AND 1921.

Special Bulletin No. 115.

BY W. C. DUTTON AND STANLEY JOHNSTON.

Pre-Pink Spraying of Apples.

The general recommendation and practice of growers in Michigan for the control of apple scab have not included any application before the blossom buds have separated in the cluster. A few growers have delayed the dormant application until the blossom buds were first swelling, thinking it to be beneficial in controlling scab when applied at that time. An occasional grower has followed the practice of making an application when the buds had advanced far enough for each bud to be easily seen but before they had separated in the clusters. This is the stage of development referred to hereafter as the "pre-pink" stage.

Studies made in several dusting and spraying experiments during 1920 and 1921 indicated that, in many instances, scab infection had occurred previously to the time the pink or cluster application was made.

Life history of scab. Apple scab is carried through the winter on the leaves which have dropped to the ground the previous fall. As soon as the leaf drops, the scab mycelium spreads from the infected spots to all parts of the leaf. In the autumn and early spring, organs known as perithecia are formed and in these perithecia the spores develop and mature, ready to be discharged when conditions are right. The discharge of these spores depends upon their maturity and the occurrence of rainy periods after they are mature. They may become mature but remain in the leaf for some time because of the prevalence of dry weather.

Spore discharge studies. The general recommendation that the first spray application be made after the buds had separated in the cluster has been based on the supposed fact that these spores were not mature and hence could not be discharged until after the buds had reached the cluster stage. Studies made in several experiments indicated that scab infections were occurring earlier than the cluster stage.

An experiment was planned for 1921 to determine if a pre-pink application is necessary. Information was desired as to the exact time the spores are mature and may be discharged, and studies to obtain this information were made by C. W. Bennett of the Botanical Section. A report of these studies is not to be included here but a brief statement of results may well be made.

The Duchess orchard on the farm of Mr. J. C. Maynard, of Grand Rapids, was to be used for the "pre-pink" spraying experiment and leaves from this orchard were collected daily and sent to Mr. Bennett who examined them to determine the condition and degree of development of the scab spores. Many spores were mature by April 4, when the first leaves were collected and by April 21 practically all were mature. The first spore discharge occurred on April 21 but the blossom buds did not separate in the cluster until April 26. The temperature was comparatively high from April 2 to 7 inclusive and the buds were forced into the "pre-pink" stage by this period of high temperature. From April 8 to 19 the temperature was low and the ground was covered with snow part of the time. The buds advanced very little during this period but the temperature was again high from April 20 to 30 and the buds developed rapidly. There were frequent rains during this period and Mr. Bennett's studies show that most of the spores were discharged between April 21 and 28. Trees in this orchard which did not receive the pre-pink application were unprotected during the greater part of the first period of spore discharge.

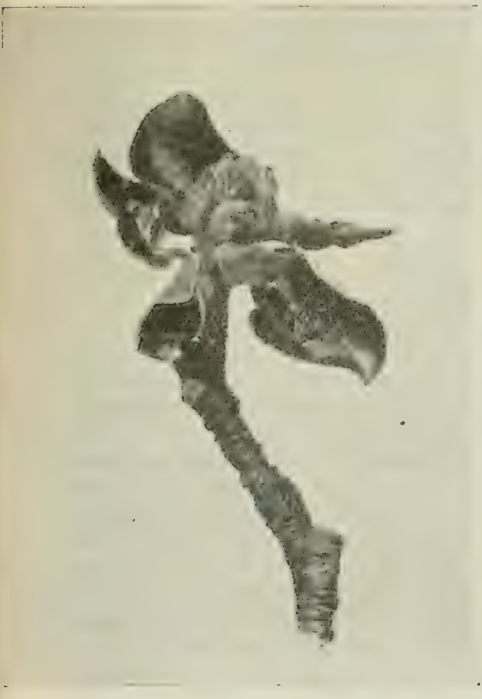

Fig. 1.—A cluster of blossom buds in a desirable stage of development for the "pre-pink" application.

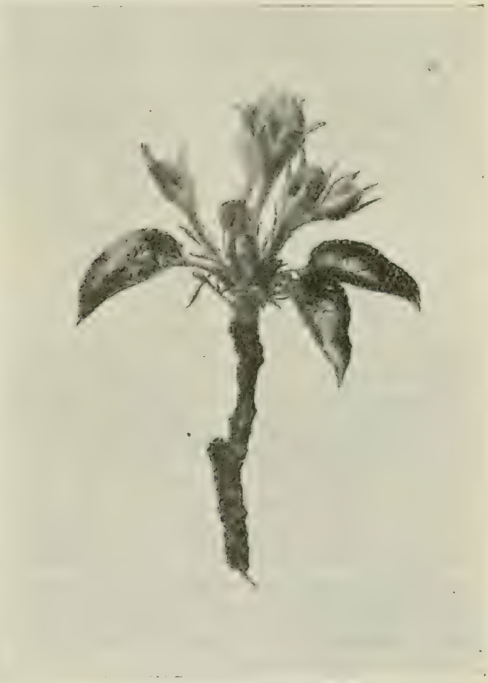

Fig. 2.—The pink or cluster stage, when apples should always be sprayed regardless of whether or not they have received a "pre-pink" application.

The studies discussed in the foregoing paragraph refer only to the first or primary discharge of spores from the old leaves and has no reference to the later formation of a different type of spores on new leaves and fruit.

Spraying experiments. The Maynard Duchess orchard, from which the leaves for spore discharge studies were secured, was used for a spraying experiment planned to get more definite information as to the value of the pre-pink application on scab control. The trees in this orchard were about seventeen years old.

Schedules of applications made. Two plots of about fifty trees each were sprayed according to the schedules here given:

Plot I. Sprayed according to "regular" schedule.
  1st. When buds had separated in the clusters.
  2nd. When petals had fallen.
  3rd. Two weeks after the second application.
Plot II. Sprayed according to "pre-pink" schedule.
  1st. When buds were in the "pre-pink" stage.
  2nd. When buds had separated in the clusters.
  3rd. When petals had fallen.
  4th. Two weeks after the previous application.
Plot III. Check. No treatment.

Both sprayed plots were treated in exactly the same manner except that one received the "pre-pink" application and the other did not. Lime-sulphur solution, 1¼-50,* was used on both plots for all applications. Lead arsenate powder was also used for all applications except the "pre-pink".

The various applications were made on the dates here listed:

"Pre-pink" application	April 8
Pink or cluster application	April 26
Calyx application	May 12
Two weeks application	May 27 and 30

Referring back to the spore discharge studies we find that no spores were discharged for some time after the "pre-pink" application and the conclusion might be made that this application was put on too early as the first spores were not discharged until April 21. This is explained by the fact that from April 8 to 20 the temperature was so low that the blossom buds did not advance. The warmer weather which followed forced the buds out quickly and apparently at the same time hastened the discharge of scab spores. The relation of temperature to spore discharge is probably very close but there is little information available concerning this. There was rainfall on April 21 and 22. The twenty-third was very warm and there was a hard rain again on April 25. The buds had separated in the cluster on the twenty-fifth but the cluster application could not be made until the twenty-sixth because of the rain. The buds were in condition for the cluster application for three days beginning with the twenty-fifth.

RESULTS.

Adverse weather conditions greatly reduced the crop but there was enough fruit produced to get definite results. An epidemic of blossom blight did much damage but there would still have been a fair crop had there not been a severe frost on May 16. The results of the counts made of Duchess are given in table 1.

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*In this and future discussions, the strength of the lime-sulphur solution is indicated in this manner; "1¼-50" means that 1¼ gallons of lime-sulphur solution has been diluted with water to make a total of 50 gallons of solution.

TABLE 1.—PRE-PINK SPRAYING OF DUCHESS APPLES, 1921

Treatment	No. of applications	No. apples examined	Scabby, per cent
Check	0	19	100
Regular schedule	3	684	46
Pre-Pink schedule	4	642	16

The "pre-pink" application resulted in a marked reduction in the amount of scab. Practically all of the 16 per cent of scab on the fruit from the "pre-pink" plot was in a very inconspicuous form and was not easily recognized as such even by careful examination. The scab on the fruit from the plot which did not receive the "pre-pink" application was in much larger and more conspicuous spots and was easily recognized.

Observations in other experiments. In several other experiments with apples the amount of scab apparently caused by infections previous to the pink or cluster application was determined. This type of scab is referred to on other pages as "early" scab. The amount of "early" scab varied from 10 per cent to 30 per cent with the different varieties. On highly susceptible varieties such as McIntosh, this form of scab developed into quite large spots which were easily noticeable but with a more resistant variety, such as Baldwin, the scab spots were small and were not easily detected.

General observations. The fruit in other orchards which did not receive the "pre-pink" application was studied whenever possible to determine the amount of scab which had been caused by early infections. Such observations were made at Grand Rapids, Belding, Fennville, Sister's Lake, South Haven and other places and the principal varieties noticed were Duchess, Wealthy, Transparent, Chenango, McIntosh and Fameuse. In nearly every orchard studied the control of the later infections was very good but in every instance there was a noticeable amount of scab which had developed from early infections.

CONCLUSIONS AND RECOMMENDATIONS.

The results of the experiments and observations here reported indicate that a "pre-pink" application is very desirable for the best control of apple scab. Further studies as to scab spore discharge and more extensive field experiments are desirable and will be continued, but the information available now justifies the recommendation of a "pre-pink" application, particularly on susceptible varieties. This application is not to be considered as a "cure-all" for apple scab but simply is one of the applications necessary in the successful prevention of scab.

All spraying for scab must be considered as "insurance" and as no grower can accurately predict what weather conditions will prevail during any given period, one cannot safely omit the application which would protect the fruit and foliage during that period. The period between the ideal "pre-pink" stage and the pink or cluster stage may be two days or two weeks in length. We do know, however, that rainy weather is apt to prevail and primary infection occur before the pink spray. In large orchards it is impossible to make any particular application at exactly the period we consider ideal; some have to be sprayed before and some after the ideal period. This would, of course, hold true with the "pre-pink" application and in seasons when the temperature is high at this period, it may be necessary to begin the pink application as soon as the "pre-pink" one is finished.

Material to use. Any of the common fungicides used for summer applications may be used for the "pre-pink" application. Bordeaux mixture should give satisfactory results at the usual strength. A stronger solution of lime-sulphur than is used during the summer may be applied with safety at this time. Some growers use it at this time at the rate of 2½ gallons in 50 and even the full dormant strength has been used without any injury other than to burn some of the first leaves which appear with the blossom buds. The dormant strength, however, is not recommended for use so late as the "pre-pink" stage as there may be weather conditions under which it would cause severe injury to the fruit buds.

COMPARATIVE DUSTING AND SPRAYING OF APPLES AND PEARS.

EXPERIMENTS WITH APPLES.

Summary of previous work. Dusting experiments with apples were begun in 1915 and have been continued in some form each year. The results of these earlier experiments have been published but will be reviewed briefly at this time. In 1915 and 1916 the control of apple scab by dusting or spraying was not satisfactory in these experiments so that no reliable comparison of the dusting and spraying methods could be made. Both of these years were very favorable for the development of scab because of frequent and heavy rains.

In 1917, 1918 and 1919 dusting and spraying gave equally satisfactory results in the control of apple scab. Weather conditions, except in 1917, were not severe and this may have had some effect on the results. Codling moth injury was not in evidence in many of the experiments but where there was any infestation the control by dusts was satisfactory.

In several experiments the foliage of trees in dusted plots was in better physical condition than that of sprayed trees. This difference was quite marked in some instances and in others there was little difference.

Object of the experiments. The experiments conducted in 1920 and 1921 were for the purpose of getting additional information as to the comparative value of the dusting and spraying methods of application, in the control of apple scab and codling moth, particularly under conditions which had not been encountered in earlier work. The effect of dusting materials upon the physical condition of the foliage was also to be studied and certain new forms of dusting materials were to be compared with the standard sulphur dust.

EXPERIMENT IN 1920.

One experiment of this nature was conducted in 1920 in a block of about 100 twelve-year-old Grimes Golden trees on the farm of Mr. H. E. Hawley near South Haven. This block was divided into four plots as follows:

1. Check—No treatment.
2. Sprayed—Dilute lime-sulphur and lead arsenate.
3. Dusted—Sulphur dust, 90-10 mixture.
4. Dusted—Dehydrated copper sulphate dust.

The dehydrated copper sulphate dust contained 10 per cent of dehydrated copper sulphate.* This material is what has commonly been called the "Sanders dust" and was developed by G. E. Sanders of Nova Scotia and has given promising results under Nova Scotia conditions. It is made by mixing the desired proportions of dehydrated copper sulphate and hydrated lime. Poison is added if desired. The dehydrated copper sulphate is prepared by heating ordinary copper sulphate (blue vitriol) to drive off the water of crystalization. It is then usually ground to produce a uniformly fine powder and mixed with the hydrated lime. When dusted on to the tree, it re-absorbs water and combines with the lime, making compounds probably similar to those obtained by mixing the two materials in water when making ordinary bordeaux. The material used in this particular experiment was made up as follows: 80 per cent hydrated lime, 10 per cent dehydrated (anhydrous) copper sulphate, and 10 per cent lead arsenate.

Applications. An equal number of applications of all materials were made as follows:

1st. When blossom buds had separated in the clusters.
2nd. When petals had dropped.
3rd. Two weeks after second application.
4th. About August 1.

All spraying was done with a power sprayer, using a spray gun. All dusting materials were applied with a large power duster and from two directions at each application. The dust was applied, generally, under favorable conditions but the foliage was frequently dry at the time the work was done.

Weather conditions. The season as a whole at South Haven was quite dry but there was considerable rainfall very early, about the time the buds were expanding, and again late in the summer when there was enough rain and fog to make conditions favorable for scab development.

RESULTS.

Control of Scab. The development of scab on the fruit of the check trees was not serious up to July 1, but it developed rapidly after that date. The foliage of the check trees, however, was very scabby at that time and served as an excellent source of infection for the fruit. At that time there was very little indication of scabby fruit on any of the treated trees and only a little infection on the foliage. When the fruit was picked, two average trees from each plot were selected as "count" trees. The fruit from them was classified into sound, scabby and wormy grades. The scabby grade included all apples which showed even a very small scab spot. The percentages of the different grades are shown in table 2.

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*This is sometimes called anhydrous or monohydrated copper sulphate.

TABLE 2.—DUSTING AND SPRAYING GRIMES GOLDEN, 1920.

Material	Number apples examined	Scab, per cent	Codling moth, per cent
Check—untreated	1489	89	10.0
Lime-sulphur solution	3518	20	1.9
Sulphur dust	2629	22	0.5
Copper sulphate dust	1705	68	5.0

These figures show the control of scab by lime-sulphur solution and sulphur dust to have been practically equal but apparently not entirely satisfactory by either. As stated above, any apple which showed even a very small spot of scab was counted as "scabby" and this included many apples which had very small scab spots around the calyx. Many of these spots were determined to be scab only by close examination and it was improbable that apples so affected would be classed as scabby in commercial grading. This point is discussed below under the heading of "commercial grades". The control of scab by the copper sulphate dust was not satisfactory as 68 per cent of the fruit from the count trees in this plot was scabby. This failure to control scab may have been due to several conditions. First, the percentage of copper sulphate in the mixture may not have been high enough; second, the dust was not always applied when the trees were wet with rain or dew and it is probable that such a condition is desirable with this material; third, this material may not be effective on apples under Michigan conditions.

Control of Codling Moth. The percentage of wormy apples on the check trees was not very high, but the control in the lime-sulphur solution and sulphur dust plots was quite satisfactory. The proportion of wormy apples in the copper sulphate dust plot was high. This dust contained the same percentage of lead arsenate as the sulphur dust but a much smaller amount per tree was used as the mixture is much lighter than sulphur dust and a given quantity covered more trees. It is possible, too, that the sticking properties of the copper sulphate dust are not so good as of the sulphur dust.

Commercial grades. It was very evident that the actual percentages of scabby fruit as shown above did not represent the true proportions of the different grades as made in commercial packing. The fruit from this orchard was graded and packed by the South Haven Fruit Exchange. To get a comparison of the experimental counts and the commercial grades, reports were secured on one full load from each of the dusted and sprayed plots.

TABLE 3.—COMMERCIAL GRADES OF GRIMES GOLDEN, 1920.

Treatment	Actual per cent of Scab	Commercial grades—per cent			
		A	B	Total A and B	Ciders
Lime-sulphur solution......	20	73	12	85	15
Sulphur dust..............	22	62	23	85	15
Copper sulphate dust.......	68	57	22	79	21

The percentages of "total A & B" for the lime-sulphur and sulphur dust plots were exactly the same. The percentage of "ciders" from these plots was considerably lower than the actual percentage of scabby fruits which shows that every apple bearing a scab spot was not graded as a cull. This is accounted for in part by the legal tolerance of imperfect apples allowed by the grading law and is further accounted for by the fact that many of the scab spots were probably not recognized as such when packed. On some of the trees there were many small apples which were graded as culls or ciders because of small size rather than because of scab or worms.

The difference in the percentages of A's between the lime-sulphur and sulphur dust plots was undoubtedly due to a larger proportion of small apples in the sulphur-dust plot, which were not affected by the dusting or spraying material used.

The point of this discussion is this. The fact that a given lot of apples packs out a certain proportion, 90 per cent for example, of A and B grades, does not mean that 90 per cent of the apples were actually free from injury by scab or insects or to express it the other way, the percentage of scabby and wormy fruit as shown by experimental counts should not be interpreted to mean that this percentage of the fruit will be culls when commercially graded.

Effect on foliage and fruit. There was no definite foliage injury by any of the materials but the foliage of dusted trees was generally brighter and cleaner in appearance than that of the sprayed trees.

EXPERIMENTS IN 1921.

Experiments of this nature were conducted in two orchards in 1921, one at Fennville on the farm of Mr. P. H. Broe and one in the Grand Traverse Peninsula on the farm of C. F. and J. W. Stickney.

EXPERIMENT AT FENNVILLE.

The six-year-old Jonathan and Wealthy orchard on the P. H. Broe farm at Fennville was used for a comparative test of spraying and dusting. These varieties were planted in alternate rows. The trees bore good crops this year.

Materials and applications. The materials used and the periods at which they were applied were as follows:

1st. When blossom buds had separated in the cluster. 90-10 sulphur dust and lime-sulphur, 1¼-50, with lead arsenate.
2nd. When petals had dropped using the same materials as for first application.
3rd. Two weeks after second application using the same materials as before.
4th. First week in July using the same materials as before.
5th. July 20 using 90-10 sulphur dust and bordeaux with lead arsenate.
6th. August 16 using 90-10 sulphur dust. No spraying material was applied.

This list of applications shows that the sprayed plot was covered five and the dusted plot six times. The lime-sulphur solution was used in this orchard for all applications except the last, because of the tendency of Jonathan apples to russet. The first and second applications were timed according to the development of the bloom of each variety, the Wealthy blossoming earlier than the Jonathan. At all other applications both varieties were treated at the same time. The dusting was always done under favorable conditions, either in the morning or evening or soon after a rain.

Weather conditions. Except during the period preceding blooming, there was not sufficient rain to make conditions favorable for scab development; but the season was very favorable for codling moth and this insect caused serious losses in most sections of the State.

RESULTS.

Jonathan. Records were obtained for this variety at harvest but there was so little injury on the check tree by either scab or codling moth that the results were not conclusive so will not be given.

Wealthy. When the crop was harvested, the fruit from the one check tree and from four sprayed and four dusted trees was graded and counted to determine the amount of injury by scab and worms.

Control of scab and codling moth. The results of the counts are shown in table 4.

TABLE 4.—DUSTING AND SPRAYING WEALTHY, 1921.

Treatment	Applications	Number apples examined	Scab—per cent		Codling moth, per cent
			Early	Late	
Check	0	142	20	79	34
Sprayed	5	561	17	8	5
Dusted	6	392	17	8	12

These figures show that dusting and spraying gave equally satisfactory control of scab but that the control of codling moth by dusting was not as good as by spraying. The "pre-pink" application was not made in this orchard so the sprays or dusts applied had no effect on the control of "early scab" as shown in the table.

Less satisfactory control of codling moth was obtained on the dusted trees in spite of the extra application to this plot made in August. The skin of the apple becomes quite waxy when nearly ripe and the dust apparently does not adhere well to the fruit at this period of development.

Effect on the foliage. There was no pronounced difference at the end of the season in the physical condition of the foliage of the dusted and sprayed plots, but earlier in the season the foliage of the dusted trees was somewhat better.

EXPERIMENT AT TRAVERSE CITY.

Another experiment was conducted at Traverse City on the farm of C. F. & J. W. Stickney. This farm is on the Old Mission (Grand Traverse) Peninsula. It lies in a narrow strip of land bordered on one side by the waters of Bower's Harbor and on the other by a high and abrupt hill. Along the front of the farm, next to the water, there is a grove of tall pine trees. These trees, on one side and the hill on the other, form a natural draw through which there were frequently strong air currents, even when there was no general wind on adjacent farms. This condition probably had a definite effect upon the results and will be discussed later.

The orchard is made up of young bearing trees of several varieties. They are Wealthy, Wagener, Winter Banana, Ontario, Jonathan, Walker's Beauty, Delicious, Sutton, Rome Beauty, and others. Most of the varieties were planted with one or two rows of a variety with Wagener as fillers.

Materials and Applications. The entire orchard was dusted with sulphur except for four cross-rows (two at the north end and two at the south end) which were left as checks. The dusting was done with a large power duster but the applications were made under conditions that were not always ideal, and that did not always permit uniform and satisfactory application of the dusting materials. Atmospheric conditions were frequently unsatisfactory.

Seven applications were made at the periods and with the materials as given below:

1st. April 29. "Pre-pink" application. Sulphur with 10 per cent of hydrated lime as a spreader.
2nd. May 4. Pink or cluster application. 80-10-10* mixture.
3rd. May 24. Calyx application. 80-10-10* mixture.
4th. June 8. Two weeks application. 80-10-10* mixture.
5th. July 8. For scab. Sulphur with 10 per cent lime.
6th. July 22. Second brood codling moth. 80-10-10* mixture.
7th. Aug. 19. For codling moth and scab. 90-10† mixture.

Weather conditions. Conditions were favorable very early in the season for scab development but were not so from the blooming period until early in July. The first rain of consequence, during the summer, fell on July 7. There was some evidence of scab which had developed earlier in the season and because the conditions were favorable to scab development, the application of sulphur was made on July 8. After that time there were other periods favorable for scab development, particularly in an orchard close to the lake.

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*80 per cent sulphur, 10 per cent hydrated lime, 10 per cent arsenate of lead.
†90 per cent sulphur, 10 per cent arsenate of lead.

RESULTS.

It was not possible to include trees of all varieties in the check plots, so the results are given only for varieties which were included in the check plot and bore enough fruit to give some definite idea of the actual results obtained. As the trees in this orchard were young, the number of apples counted was not large.

TABLE 5.—DUSTING APPLES AT TRAVERSE CITY, 1921.

Variety	Check			Dusted		
	Total No.	Scabby, per cent	Wormy, per cent	Total No.	Scabby, per cent	Wormy, per cent
Wagener	129	66	35	168	14	9
Ontario	117	24	11	94	6	7
Jonathan	125	28	12	159	4	7
Walker's Beauty	82	34	41	67	11	14
Delicious	102	66	4	120	51	....
Rome Beauty	31	84	16	54	11	13

Definite counts were not made for Wealthy, but one bushel of fruit from dusted trees and an equal amount from check trees was examined by Mrs. Stickney who reported that in the bushel of dusted apples there were only seven culls, while in the bushel from the check trees there were only eleven which were not culls.

All apples were classed as "scabby" which showed even a very small scab spot and this of course included many which were not really culls. In the "wormy" grade, all apples showing "stings" were included, although a "sting" is evidence that the poison was effective as a worm must eat before it can be poisoned.

The control of scab was not uniform with all varieties. This was due, in part, to certain mechanical difficulties with the duster and to irregular air currents before mentioned. These conditions made uniform application impossible. The difference in susceptibility of the varieties also probably affected the results. The differences in the blooming period of the several varieties made it impracticable to apply the dust at the most ideal time for each variety. The Delicious, a late blooming variety, was very scabby as the "pre-pink" and pink applications were not timely for this variety.

GENERAL STATEMENT OF RESULTS OF APPLE DUSTING WORK.

Scab control. Sulphur dust has continued to give satisfactory control of apple scab. This statement refers to its use in the regular summer schedule. beginning with the cluster application. The value of sulphur dust when used for the "pre-pink" application has not been fully determined and further work along this line is necessary and is planned for the coming season.

Copper sulphate dust, in the proportions used, so far has not given satisfactory results on apples.

Codling moth control. In 1920 when there was about the average amount of codling moth injury, the dusting method gave satisfactory control but in

1921 when codling moth injury was very severe late in the season, dusting did not give as good results as spraying. This condition was found at Fennville in the experiment with Wealthy and in other experiments not reported in detail in this bulletin.

Experiments With Pears.

Pear scab has caused serious losses in recent years in orchards in southwestern Michigan. Many of the best growers have complained that the usual spraying schedule has not been giving the desired results. This schedule consists of three applications as follows:

1st. When buds are separated in the cluster.
2nd. Just after petals have dropped.
3rd. About two weeks after second application.

Experiments were planned to determine if more spraying is necessary under Michigan conditions to satisfactorily control pear scab. Information was also needed concerning the efficiency of dusting materials when used on pears, so a considerable portion of the experiments consisted of a comparison of the dusting and spraying methods of application with particular attention to the control of scab and the effect on the foliage.

EXPERIMENTS IN 1920.

Experiments were conducted in two orchards at South Haven in 1920. One was on the H. E. Hawley farm and the other on the farm of H. E. Merritt.

EXPERIMENT ON THE MERRITT FARM.

The work on this farm was conducted in a block of 250 ten-year-old Bartlett trees. The orchard in which this block is located stands almost on the bank of Lake Michigan. The trees had produced little fruit in previous years but most of them bloomed full in 1920.

Materials and applications. The block of trees was divided into three large plots and one small plot, the small one being left untreated as a check. Each of the large plots was treated with a different material as here listed.

1. Lime-sulphur solution, 1-50.
2. Sulphur dust.
3. Copper sulphate dust. 10 per cent dehydrated copper sulphate.
4. Check. Untreated.

Lead arsenate was used in combination with these materials when necessary.

The applications were made as follows except that part of each did not receive the "pre-pink" application.

1st. "Pre-pink" application. When buds first showed color but had not separated in the cluster.
2nd. Pink or cluster application. When buds had separated in the cluster. All parts of every plot, except the check, received this and later applications.
3rd. Calyx application. Just after the petals had dropped.
4th. About two weeks after the third application.

The spraying was done with a spray gun and with a sprayer which maintained a pressure of about 225 pounds. A large power duster was used for dusting and the material was applied from two directions at each application. The work was usually done early in the morning but atmospheric conditions were not always satisfactory.

The description of the experiment in the Hawley orchard will be given here and the results of both experiments will then be discussed together.

EXPERIMENT ON THE HAWLEY FARM.

Another experiment was conducted on the H. E. Hawley farm in a block of 100 twelve-year-old Bartlett trees. This orchard is farther from the lake. Most of the trees bore a fair to good crop of fruit in 1920 but in 1919 there was such a light crop that very little spraying was done and much scab developed.

Materials and applications. This block was divided into four plots and treated with the same materials as listed in the preceding discussion of the Merritt experiment. The only difference being that lime-sulphur was used at the rate of 1-40 instead of 1-50. The applications were made at the same periods as in previous experiment but all of each plot received the "pre-pink" application. This experiment, then, was a comparative test of lime-sulphur, sulphur dust and copper sulphate dust, applied according to a schedule which calls for the first application when the buds are in the "pre-pink" stage.

Weather conditions. The early part of the season was very favorable for scab development because of frequent rainfall during the period when the blossom buds were expanding. The control of scab during this period was difficult because of cool weather which prevailed for some time after the buds had reached the "pre-pink" stage. The buds developed slowly and there was excellent opportunity for scab infection on portions of the blossom stems or buds that became exposed after the "pre-pink" stage but before the time of the pink application. After the blooming period the weather was quite dry and unfavorable to scab development. This statement of weather conditions applies to both orchards, although the conditions during the summer were probably more favorable for scab in the Merritt orchard because of its proximity to the lake.

RESULTS.

Scab control. Counts were made in the Merritt orchard from a bulk lot of fruit picked from a large number of trees of each plot. Counts giving the results of the "pre-pink" application were made only on the sulphur dust plot because of the light crop. The number of applications given each group in the following table is indicated by the numbers in the column headed "applications". Number 1—refers to the "pre-pink", 2—to the pink or cluster, 3—to the calyx application, and 4—to the one made two weeks after the calyx application.

TABLE 6.—DUSTING AND SPRAYING BARTLETT PEARS, MERRITT ORCHARD, 1920.

Treatment	Applications	Total number fruits	Scabby, per cent
Lime-sulphur, 1—50	1, 2, 3, 4	1170	10
Sulphur dust	1, 2, 3	1264	15
Sulphur dust	2, 3, 4	781	22
Copper sulphate dust	1, 2, 3, 4	1249	23
Check	0	285	58

Lime-sulphur spray gave better control of scab than the best dusted plot, but in comparing the two plots the fact that the sulphur dust plot did not receive the fourth application must be considered. The point of greatest interest is that the sulphur dust plot receiving the "pre-pink" application showed 7 per cent less of scab than the plot not receiving the "pre-pink". The copper sulphate dust did not give satisfactory results even with the full schedule of four applications.

In the Hawley orchard four average trees were selected from each plot for "count" trees and the fruit from these trees sorted and counted to determine the amount of scab present. The results are given in table 7.

TABLE 7.—DUSTING AND SPRAYING BARTLETT PEARS, HAWLEY ORCHARD, 1920.

Treatment	Applications	Total number fruits	Scabby, per cent
Lime-sulphur, 1—40	1, 2, 3, 4	2947	16
Sulphur dust	1, 2, 3, 4	4358	10
Copper sulphate dust	1, 2, 3, 4	3806	20
Check	0	2991	60

In this orchard sulphur dust gave better results than lime-sulphur. Copper sulphate dust failed here to give satisfactory results.

In the Hawley orchard, sulphur dust gave better results than lime-sulphur but in the Merritt orchard lime-sulphur gave more satisfactory results than sulphur dust. This difference may be accounted for in part by the difference in application in the two orchards. At the Hawley orchard the dusting was usually more efficiently done than the spraying due to mechanical trouble with the sprayer, while at the Merritt orchard the spraying was done in a more satisfactory way due to atmospheric conditions which were unfavorable to efficient dusting.

Effect on foliage. Throughout the season, there was a marked difference in the condition of the foliage of the several plots. The lime-sulphur spray caused considerable foliage injury most of which developed after the calyx application. This injury was not general over the trees but was limited to small areas which probably received a heavier application or were closer to the spray gun so that the material was driven against the leaves with greater force. The foliage of all dusted plots was in excellent condition at all times.

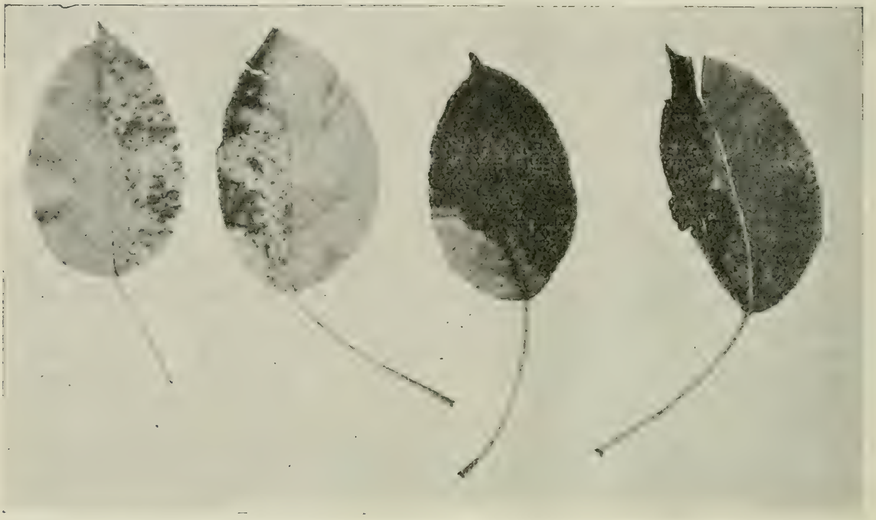

Fig. 3.—Typical leaves from a Bartlett tree sprayed with dilute lime-sulphur (Hawley orchard, 1920). The injury there was scattered but severe in some places.

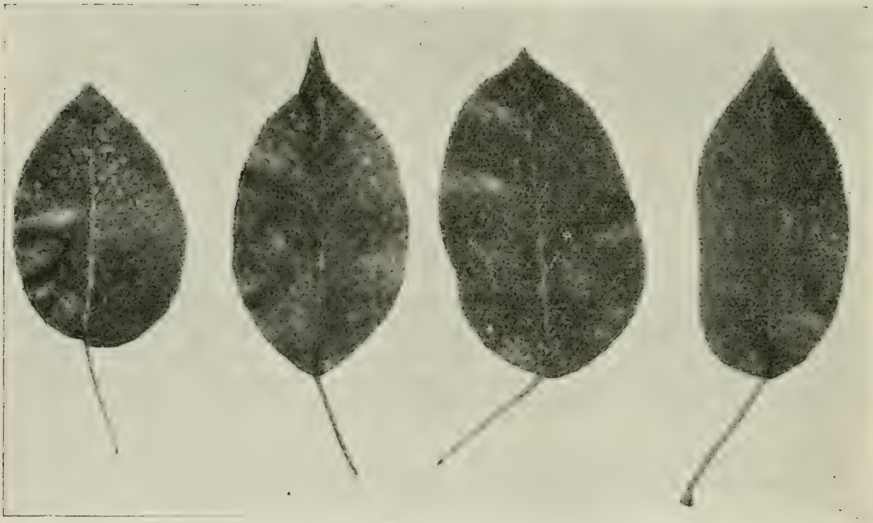

Fig. 4.—Typical leaves from a Bartlett tree dusted with 90-10 sulphur-lead dust. There was no injury and the physical condition was good.

EXPERIMENT AT FENNVILLE.

Further work with pears to compare dusting with spraying was conducted in the P. H. Broe orchard at Fennville. The trees in this orchard are mature and are of several varieties. Although all varieties were dusted or sprayed alike, the Bartlett was the only one considered in the results.

Materials and applications. The experiment started with the pink or cluster application; both plots having received a "pre-pink" (or delayed dormant) application of lime-sulphur, 6¼-50, for pear psylla control. This spray was undoubtedly of great value for the control of scab this year, as weather conditions very favorable for scab development prevailed during the period when the buds were expanding. No check plot was left because of the necessity to spray for pear psylla.

Three other applications for scab control were made after the "pre-pink" stage.

1st. When buds had separated in the clusters.
2nd. Calyx application.
3rd. Two weeks after second application.

For the first application sulphur alone was used on the dusted plot and bordeaux mixture on the sprayed plot. For the calyx application Niagara "All-in-One Mixture", containing sulphur, lead arsenate and nicotine sulphate was used on the dusted plot and on the sprayed plot lime-sulphur, 1 to 40, lead arsenate and Black Leaf 40 were used. For the third application 90-10 sulphur-lead dust and bordeaux mixture with lead arsenate were used. The dusted plot received an application of "All-in-One Mixture" on July 8 for pear psylla but the sulphur and lead arsenate in it was undoubtedly beneficial for the control of scab and worms.

RESULTS.

Scab control. When the fruit was picked, the crop from three dusted trees and three sprayed trees was sorted and counted with the results shown in table 8.

TABLE 8.—DUSTING AND SPRAYING BARTLETT PEARS, BROE ORCHARD, 1921.

Treatment	Total No. pears counted	Scabby, per cent	Wormy, per cent
Dusted	2103	1.9	0.5
Sprayed	1436	3.1	1.3

The percentage of scab on the fruit from both plots was very low and practically all the scab was in very small spots. There were only two or three pears in each lot which were badly scabbed. When comparing these results the fact that both plots received a "pre-pink" application of lime-sulphur spray must be considered. This early application, as stated above, was probably very important in the control of scab this season, as the period when the buds were expanding was the only time during the season when weather conditions were really favorable for scab development.

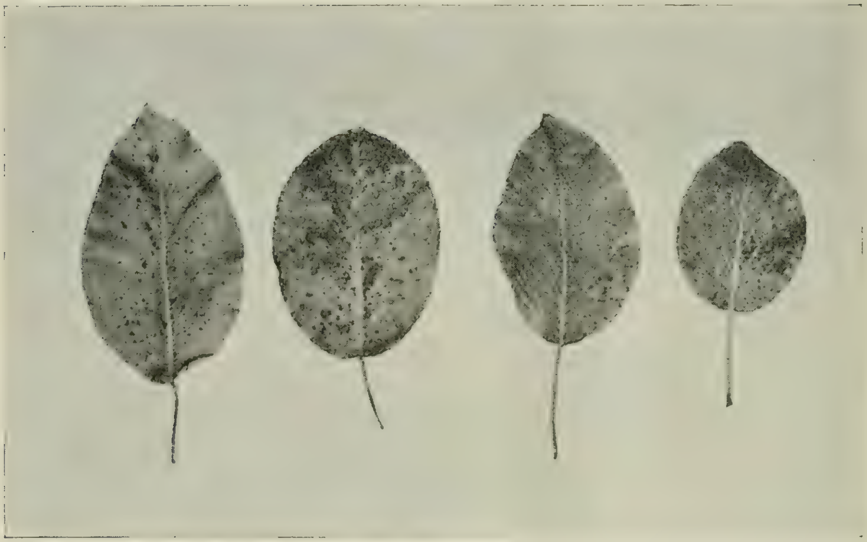

Fig. 5.—Typical leaves from a Bartlett tree sprayed with dilute lime-sulphur (Broe orchard, 1921). This injury developed within twenty-four hours after application.

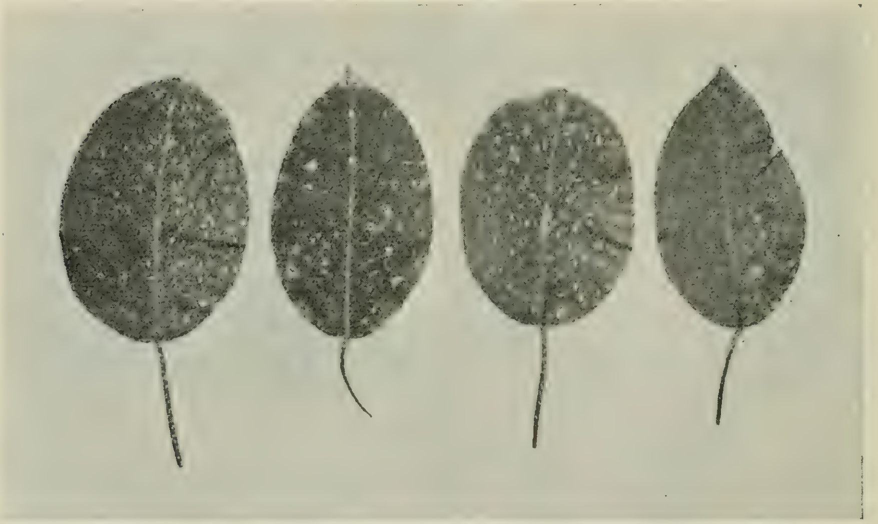

Fig. 6.—Typical leaves from a Bartlett tree sprayed with bordeaux (Broe Orchard, 1921). The physical condition is excellent·

Effect on the fruit and foliage. The "finish" of the pears from dusted trees was very much superior to the finish on fruit from sprayed trees which developed considerable russet.

The foliage of all dusted trees was in excellent condition throughout the season. The lime-sulphur which was used for the calyx application caused severe foliage injury but this injury was not found on trees sprayed with bordeaux at that time. The lime-sulphur injury developed within twenty-four hours after the application of the spraying material.

CONCLUSIONS FROM RESULTS OF PEAR DUSTING AND SPRAYING EXPERIMENTS.

Value of the "pre-pink" or delayed dormant application. The results of work in 1920 and 1921 indicate that an application, made just as the blossom buds first show white but have not separated in the cluster, is valuable in the control of pear scab. It seems advisable from experiments conducted thus far that this application be made in districts where pear scab is prevalent and in all sections on varieties which are very susceptible.

Any of the spraying materials ordinarily used for pears are satisfactory for the "pre-pink" application. Lime-sulphur, 6¼-50, may be safely used at this time when pear psylla is prevalent.

Comparative value of dusting and spraying. The control of pear scab in the work here reported has been about equally efficient by dusting and spraying, but further tests under different weather conditions will be necessary before any definite statement can be made. The foliage on dusted trees and on those sprayed with bordeaux has always been better than on trees sprayed with lime-sulphur.

Some Observations on the Control of Pear Psylla.

The severe outbreak of pear psylla in many districts in 1920 resulted in many demands for information and emphasized the difficulty of controlling this insect satisfactorily with the methods ordinarily used. The treatment which has been generally recommended in Michigan consists of a general cleaning up of the orchard, scraping the bark and making a dormant application of nicotine sulphate or of a miscible oil in the late fall or early spring to kill the hibernating adults.

There have been many indications that this treatment will not give satisfactory results when the psyllas are numerous as many of them do not hibernate on the pear trees but return to them in the spring to lay their eggs.

Other methods of control. The fact that the eggs are all deposited on pear trees and may be destroyed by certain spraying materials offers another opportunity for attack. When using this method of treatment one application is made just before the blossom buds begin to separate in the clusters to destroy the eggs and another soon after the petals fall to kill nymphs which have hatched from eggs deposited after the first application or from eggs which escaped injury by it.

As this method had not been generally used in Michigan, it was necessary to obtain more information as to the best material to use for the first application. This information was obtained through the co-operation of the Section of Entomology. A supply of hibernating psylla was secured from Fennville and placed with pear twigs in cages in the Entomological Department insectary. Great numbers of eggs were deposited on the pear twigs which were then treated with several materials and combinations of materials and at various concentrations to determine which one would be most effective in killing the eggs. A report of this work is not desirable here except that the results of this work indicated that lime-sulphur solution, 6¼-50, is effective for killing psylla eggs. Similar results have been obtained by workers in other districts.* The recommendation that lime-sulphur solution, 6¼-50, be used for killing psylla eggs was then made by the Sections of Entomology and Horticulture.

Field observations. In order to know how successful growers were in controlling pear psylla by this and other methods, observations were made throughout the season in several orchards, most of which were in the Fennville district. The orchards in which observations were made will be referred to hereafter by number and the spraying was in nearly every instance done by the orchard owners.

ORCHARD NUMBER 1.

This orchard is located in the Fennville district and contains several thousand pear trees of various varieties. The trees are mostly mature. The infestation of pear psylla was very severe in one block in 1920 but not so bad in the others.

Spraying operations. The block that was seriously infested in 1920, and will be referred to as Block A, was sprayed in late November, 1920, with lime-sulphur, 6¼-50, and nicotine sulphate (Black Leaf 40) 1 pint in 100 gallons. The bark of these trees was quite smooth as the trees had been thoroughly scraped about one year previously. There had been no sharp freeze to drive the psylla into hibernating quarters and the leaves were barely off the trees at that time. The weather was mild and continued so throughout December so that the psylla were active unusually late. This application was undoubtedly effective against all psyllas hit and the orchard was quite free from them for about two weeks but after that time they were present in increasing numbers. They probably were working back into this orchard from fence rows, other kinds of trees and from a neighboring pear and apple orchard just over a fence.

Block B, which is located on another portion of the farm, was not sprayed in the fall and had not been seriously infested with psylla in 1920. By early April 1921, almost inconceivable numbers of eggs had been deposited on the trees of this block. Eggs were much more numerous here than in Block A which had been sprayed in November.

All pear trees on the farm were sprayed between April 7 and 12 with lime-sulphur, 6¼-50. At that time the blossom buds of Kieffer had mostly separated in the clusters; Bartlett buds were just beginning to separate and Bosc buds were much slower in opening than those of the Bartlett. The spraying was all done with spray guns, with one man to each spraying outfit. Most of the work was done with the man working from the ground.

The entire orchard was again sprayed just after the petals fell for psylla, using nicotine sulphate, 1 pint to 100 gallons, in combination with dilute lime-sulphur or bordeaux, and arsenate of lead.

During May when the nymphs of the first summer brood were prevalent in unsprayed orchards they were found here, in both Block A and B, in limited numbers, but plentiful enough to cause serious infestation from later broods provided weather conditions were favorable.

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*Hodgkiss, H. E., N. Y. Agr. Exp. Sta. Bul. 387; Ross, W. A. and Robinson, W., Report Entomological Society of Ontario, 1919.

By the middle of June the nymphs of the second summer brood were present in large numbers and were causing serious injury to the foliage. This condition prevailed in Block A which had received the dormant application for the hibernating adults in addition to the applications made on Block B. The smaller number of eggs in Block A early in April was not reflected in a less serious infestation in June as the nymphs were present apparently in about equal numbers in both blocks.

This condition indicates that the fall application was really of little value in this instance for which there are two probable reasons. First, there were as many eggs escaped injury from the application of strong lime-sulphur in Block A as in Block B, and second, there were probably equal numbers of eggs deposited in both blocks by belated females.

Summer applications. Several materials and combinations of materials were used from June 18 to 22 to kill the nymphs of the second summer brood. They were as follows:

1.	Black Leaf 40	1 pint	100 gallons water
	Hydrated lime	20 pounds	
2.	Black Leaf 40	1 pint	100 gallons water
	Casein	2 ounces	
	Hydrated lime	6 ounces	
3.	Black Leaf 40	1 pint	100 gallons water
	Whale oil soap	3 pounds	
4.	Hydrated lime	20 pounds	100 gallons water

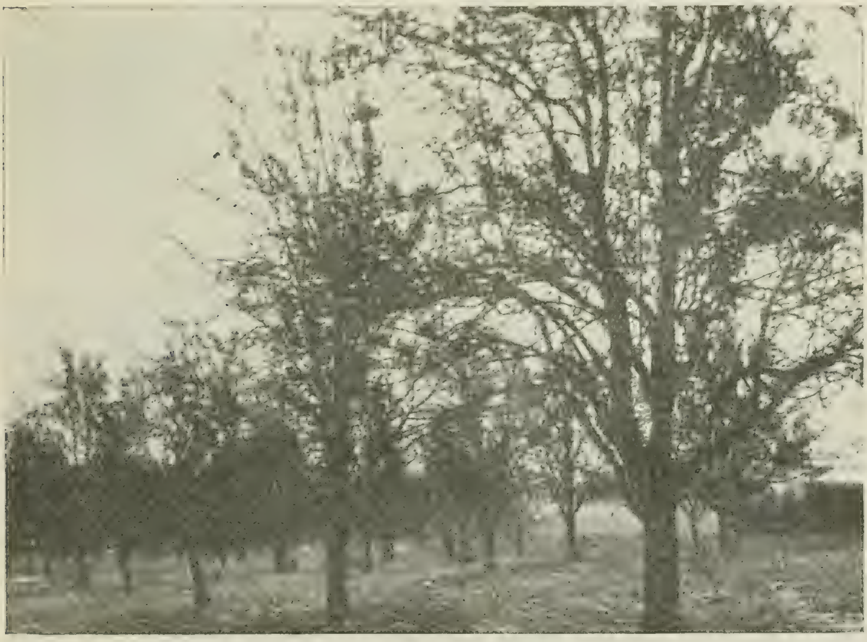

Fig. 7.—A view in Orchard No. 1 in which control was not satisfactory. The trees were practically defoliated in early September. This orchard received the dormant application for hibernating adults, the delayed dormant for the eggs and a calyx application for nymphs. Picture taken in September, 1921.

A 200-gallon tankful of each of these combinations was used and the trees were covered as thoroughly as was possible for one man working from the ground with a spray gun. These materials were applied to a section of Block B and at least half the block was not sprayed at that time.

The results from the use of all these materials were very marked. The hydrated lime alone killed practically all the nymphs which were on the surface of the leaves but did not kill many of those feeding around buds or at the base of leaf stems on tender growth. All of the combinations in which Black Leaf 40 was used gave satisfactory results and almost completely eradicated the psylla from the trees treated with them. There was a strong contrast in the condition of the trees sprayed in June and the surrounding trees not sprayed at that time. This difference in condition was apparent until late in the season. The adult psyllas had then spread into this sprayed section of the orchard, from the section not sprayed in June, in such numbers as to cause serious injury during September.

Practically all mature trees in all parts of the orchard were badly defoliated by the injury from a large brood of nymphs which developed in early September.

Remarks. It is impossible to tell exactly why the results in this orchard were not satisfactory, but the failure to cover all portions of the trees with spraying material, particularly at the calyx application, was undoubtedly an important reason why the control was not satisfactory. The owner of the orchard and others who followed the work closely agree that the spraying was not really done as thoroughly as was thought at the time of application.

ORCHARD NUMBER 2.

This orchard is in the South Haven district. The trees are Kieffer about seven or eight years old. This orchard was sprayed very thoroughly about March 15 with strong lime-sulphur and Black Leaf 40 to kill the hibernating adults. The trees were examined on March 24 and many active adults were found. It is believed that these had migrated to the pear trees from other hibernating quarters after the application was made, especially when the thoroughness with which the spraying was done is considered.

ORCHARD NUMBER 3.

This orchard is an extensive planting near Fennville of mature, closely set trees of several varieties. There was a very heavy infestation of psylla in the fall of 1920 and great numbers of eggs were deposited on these trees in late March and early April of 1921. The orchard was sprayed just before blossoming with lime-sulphur, 6¼-50. The application was begun when the blossom buds of Kieffer were mostly separated, but the spraying was not completed until the later blooming varieties were in full pink. There were prospects for only a light crop of fruit so little consideration was given to the effect of the spraying material upon the flower buds. Another application was made about one week after the petals fell, using Black Leaf 40 in combination with dilute lime-sulphur and lead arsenate. Both applications were made in a thorough manner.

Results. These two thorough applications gave almost complete control of the psylla and it was very difficult at any time during the entire season to find psylla in any form. The orchard was last visited in early October and at that time the foliage was in excellent condition. Another item of interest was the effect of the strong lime-sulphur on pear-leaf blister mites which had become well established on the young leaves. The lime-sulphur killed most of the leaves which had developed at the time of application and at the same time effected a thorough clean-up of the mites.

ORCHARD NUMBER 4.

This orchard is also near Fennville and the trees under observation were mostly Kieffer. One block of mature trees was sprayed with lime-sulphur, 6¼-50, just after the blossom buds had separated but did not receive an after-blossom application of nicotine sulphate. The control by this one application was not satisfactory as nymphs of the second summer brood were present in June in considerable numbers. A few isolated trees near this block which were not sprayed at all for psylla control were seriously infested in June.

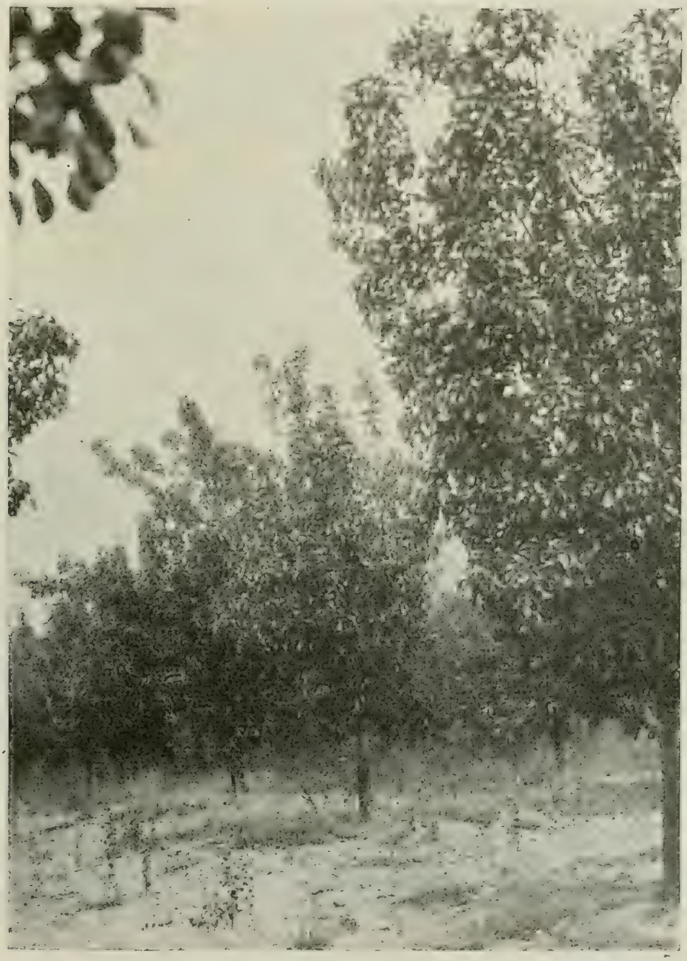

Fig. 8.—A view in Orchard No. 3, showing condition of trees where the psylla had been controlled by two thorough applications, one before blossoming to destroy the eggs and one after blossoming to destroy the nymphs. Picture taken Oct. 8, 1921.

A portion of another block in this orchard was not sprayed until about one week after the petals had fallen. At that time a mixture suggested by Ross* was used. It was made up as follows:

Lime-sulphur solution, 2½ gallons
Hydrated lime, 10 pounds
Lead arsenate (powder), 1¼ pounds
Black Leaf 40, 1 pint
Water to make up to 100 gallons

An unusually thorough application was made, using a rod with an angle nozzle. The trees are not so high but that they could be thoroughly sprayed by one man working from the ground with a spray rod.

These trees were carefully examined in June and again in September and October. Only a few psylla were found at any time and the foliage was in good condition at all times.

Other orchards. Observations were made in several other orchards but a statement of applications and results would be mainly a repetition of statements already made. While a detailed statement of these observations will not be included, the results have been considered in drawing general conclusions of the work.

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*Wm. A. Ross, Entomological Laboratory, Vineland Station, Ontario.

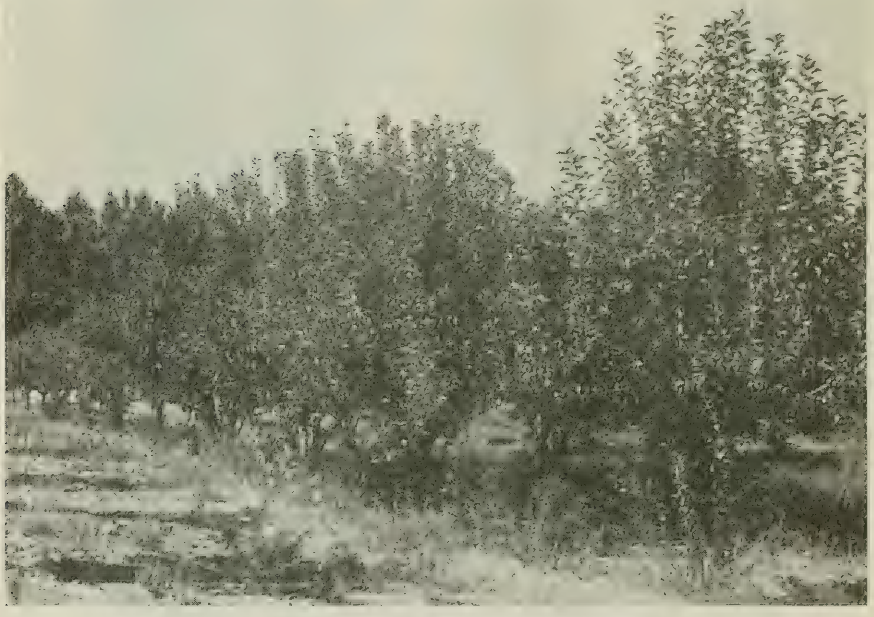

Fig. 9.—A view in Orchard No. 4 in which pear psylla was quite completely controlled by one application about one week after the petals had fallen. Picture taken Oct. 7, 1921.

Injury to foliage and flower buds. The strong lime-sulphur, 6¼-50, applied just before the blossom buds separated or any time during the cluster stage caused considerable injury to the first leaves in nearly every instance but this injury was never permanent and it was not possible to tell by a casual examination after the blossoms had dropped that any such injury had occurred.

In some orchards considerable injury occurred on the blossom buds and in others there was very little of such injury. There seemed to be a varietal difference in susceptibility to such injury; Kieffer apparently being the most susceptible. This difference may have been more apparent in some instances than actually existed as Kieffer blooms earlier than most varieties and the application was usually timed by most growers for an average of all varieties so that Kieffer was the most advanced and consequently more tender. Low temperatures after the application undoubtedly increased the injury. There were several severe frosts during the period when the buds were expanding and before the blossom buds had opened. Trees which were sprayed before these frosts lost many more blossom buds than trees sprayed after the period of low temperature. One grower sprayed early in the forenoon of a day when the temperature had dropped to twenty-three degrees in the morning. The sprayed trees lost many buds while unsprayed trees did not. There were very few places where the final yield of fruit was seriously reduced in spite of apparently severe injury to blossom buds in the spring.

Effect of hot, dry weather. The psyllas were greatly reduced in many orchards by a period of hot dry weather which prevailed during July. The final effect was different in various orchards and was probably directly related to the vigor of the trees. In orchards of high vigor and with heavy foliage the setback to the psyllas was only temporary as they developed again in serious numbers in September. In orchards of lower vigor and with sparse foliage, they were reduced to such an extent that they caused little injury later. In the South Haven district they were evidently reduced to insignificant numbers in nearly all orchards as little injury was reported late in the season.

SUMMARY AND GENERAL REMARKS.

The dormant application to kill the hibernating adults under conditions prevailing during the fall and spring of 1920-21 was not effective in orchards under observation. (Orchards No. 1 and 2.)

Two applications, one before blossoming to destroy the eggs and one after blossoming to kill the nymphs, were very effective in some orchards (Orchard No. 3) but in other orchards the same or a greater number of applications was not effective (Orchard No. 1). The failures in the latter instances are probably due to the fact that the applications were not as thorough and complete as is necessary for the control of pear psylla.

In one orchard satisfactory results were obtained from the use of but one application after the petals had dropped with a mixture containing lime-sulphur, lead arsenate, hydrated lime and nicotine sulphate. This demonstrates the possibility under favorable conditions of cleaning out the psylla with summer applications. (Orchard No. 4.)

The thorough use of nicotine sulphate in any one of several combinations will be effective at any time during the summer when the psyllas are in the nymph stage but the summer sprays are not efficient when used against the adults. (Orchard No. 1.)

Hot and dry weather materially reduces the number of psyllas but later broods of that season may develop to serious proportions when weather conditions again become favorable.

Injury to the first leaves nearly always develops after the use of strong lime-sulphur to destroy psylla eggs, but such injury is not serious nor permanent. Flower buds may be injured under some conditions and some varieties seem more susceptible than others. Freezing temperatures following the application have a tendency to increase such injury. In order to avoid injury to the blossom buds it is advisable to make the application of strong lime-sulphur not later than when the buds have begun to separate in the cluster and as some varieties blossom earlier than others each one should be sprayed when it reaches the proper stage of development.

The practice of spraying with strong lime-sulphur just before the blossom buds have begun to separate in the cluster has several advantages aside from its value in destroying psylla eggs. San Jose scale should be effectively controlled at this time; pear leaf blister-mite will be greatly reduced and in districts where pear scab is prevalent it takes the place of the "pre-pink" application for scab control.

Thoroughness of application is a factor of greatest importance and cannot be emphasized too strongly. When spraying to destroy the eggs or hibernating adults every portion of the tree must be covered and when spraying to destroy the nymphs during the summer, thoroughness is even more essential as many of them are likely to be in protected places and every one that escapes may mean a greatly increased number in succeeding broods. The method of application will naturally vary under different conditions but where mature trees are to be sprayed it is suggested that the work be done by two men; one on top of the sprayer or preferably in a tower and one on the ground. A spray rod with angle nozzle can undoubtedly be used more efficiently than a spray gun by a man spraying from the ground.

THE CONTROL OF BROWN ROT ON PEACHES AND PLUMS.

The loss of fruit in transit. The excessive losses in recent years by growers of peaches, plums and cherries has led the Horticultural Section to carry on a series of experiments to determine if such losses may be prevented. The fruit has been harvested, apparently in good condition, but has decayed sometimes before shipment, but more often while in transit or before finally taken by the consumer. With peaches and plums the trouble has usually been caused by brown rot; with cherries it may have been caused by brown rot in some instances but has usually been caused by some other organism such as white mold.

In order to avoid such losses it has been necessary to harvest some kinds of fruit, particularly plums, before they have reached a state of maturity which would develop the best quality and color. The practice of putting fruit upon the market in an immature state has probably curtailed consumption and reduced the price in some instances. The consumption of commercially canned plums has undoubtedly been reduced because of the low quality of fruit which has been picked prematurely. It is evident that any treatment which will prevent losses in transit or permit the fruit to develop more color and flavor would be welcomed by the growers, dealers and consumers.

Experimental work to develop methods of control. A series of experiments was conducted in 1920 and 1921 to develop, if possible, a satisfactory method of improving the shipping and holding quality of peaches and plums through the control of brown rot at this period. It seems that a late application of a fungicide, that would remain on the fruit after it was harvested, without staining or otherwise being apparent, would be very beneficial. Sulphur dust seemed to be the material that best fulfilled these particular requirements so was used in an experimental way with the results herein reported.

EXPERIMENTS IN 1920.

Experiment at South Haven. The first work of this nature was conducted near South Haven on the H. E. Hawley farm in 1920.

The variety was Lombard. The trees were 10 years old and in full bearing. Many of the trees bore quite heavy crops and none of them were thinned. The control of brown rot before harvesting under such conditions was more difficult than if the trees had been properly thinned.

Materials Used. Two materials were used in the experiment which were as follows:

1. Lime-sulphur solution, 1¼-50. Lead arsenate was used in combination at the rate of 1¼ pounds in 50 gallons.
2. Sulphur dust, 90-10 mixture. Sulphur alone was used for the later applications.

The orchard was divided into two large plots for each of the materials and one small plot which was left untreated as a check. The sprayed plot contained about 60 trees and the dusted plot about 95 trees. The check plot which contained eight trees was located in a corner of the sprayed plot as far as possible from the dusted plots so as not to be affected by any drifting dust.

Applications. The dusting materials were all applied with a large power duster and the work was usually done in the morning or evening but there was frequently some wind blowing so that conditions were not ideal for dusting. The spraying was done with a power sprayer which usually maintained a satisfactory pressure. A spray gun was used. Applications were made at the periods and with the materials indicated below.

1st. Just before blossoms opened. Both plots were treated.
2nd. Just after blossoms fell. Both plots were treated.
3rd. Two weeks after second. Both plots were treated.
4th. July 9. Sulphur dust plot treated with 90-10 mixture from one side of trees.
5th. About one month before harvest. Both plots were treated but no lead arsenate was used.
6th. One week before harvest. Sulphur dust plot was treated with straight sulphur.

RESULTS.

Control of brown rot before harvest. The following note was made on June 21, "All trees have a few plums affected with rot, the infection apparently having been made in every case through curculio stings. The rot does not seem to be spreading and is found uniformly on dusted, sprayed and check trees." This early infection did not spread at the time but was probably responsible, in part, for an occasional rotted cluster later in the season. As stated earlier, the fruit was not thinned and it would be difficult to stop the spread of brown rot in a cluster of fruit if one had become infected through a curculio sting.

After August 1st, while an occasional cluster affected by brown rot could be found on both the dusted and sprayed plots, it did not become at all serious at any time on these plots, so that at harvest both were in excellent condition.

Brown rot developed gradually on the check trees until picking time when the fruit on several trees was not worth harvesting.

Control of brown rot after harvest. One bushel of fruit was picked from each plot, care being taken that no rotten fruit was included. The sample from the check plot was taken from the trees in the best condition. The results are here stated as follows:

After three days the fruit from the check plot was entirely decayed and worthless.

After six days the dusted fruit was in excellent condition but that from the lime-sulphur plot was almost all decayed.

After twelve days at least one-half the dusted fruit was still sound.

These results, then, show the relative value of no treatment with the regular summer sprays and with the regular sprays plus a late application of dust to improve the keeping quality of the fruits. The results secured by both dusting and spraying in the control of brown rot up to the time the fruit was harvested were very good. The late application of sulphur dust was valuable in preventing the development of rot after the fruit was picked.

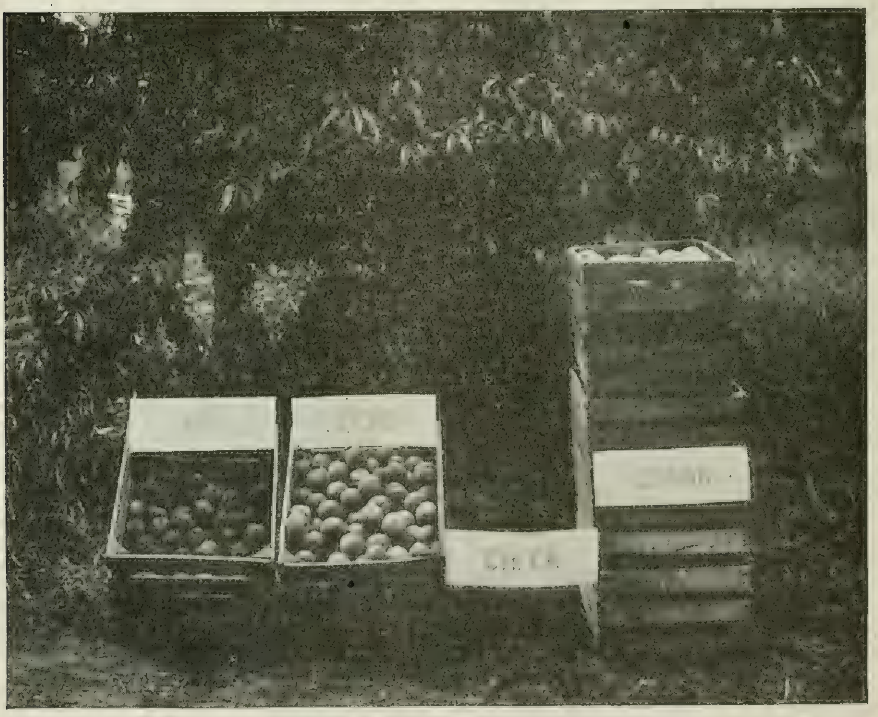

Fig. 10.—Fruit from check trees showing the proportion of sound, scabby and rotten peaches.

EXPERIMENTS IN 1921.

This work was continued and expanded in 1921. A series of experiments was conducted with peaches and plums at Hart in the orchards of Geo. A. Hawley and Son and at Fennville with peaches in the orchard of P. H. Broe.

Experiment at Fennville. The five acre orchard of Mr. P. H. Broe was used for this season. It contains approximately five hundred mature trees, and is about equally divided into two blocks, one of Elberta and one of Salway. The orchard was one of the very few in the Fennville district which was not seriously injured by the late freezes. The trees of both varieties bore uniformly full crops; in fact, they set so much fruit that severe thinning was necessary.

Object of the experiment. This work was planned to determine whether sulphur dust would control curculio, peach scab and brown rot (which develops before harvest). The effect of sulphur dust on the foliage and the color of the fruit was also to be considered. A "holding test", to determine the effect of the dust upon the development of brown rot after harvest, was made with Salway.

Materials Used. The only material used was sulphur dust, no spraying of any kind being done during the summer. The entire orchard was dusted except three cross rows along the south end of the orchard which included trees of both Salway and Elberta. The dust used for the early application contained lead arsenate and was made up in the proportion of: 75 per cent dusting sulphur, 15 per cent hydrated lime, 10 per cent lead arsenate.

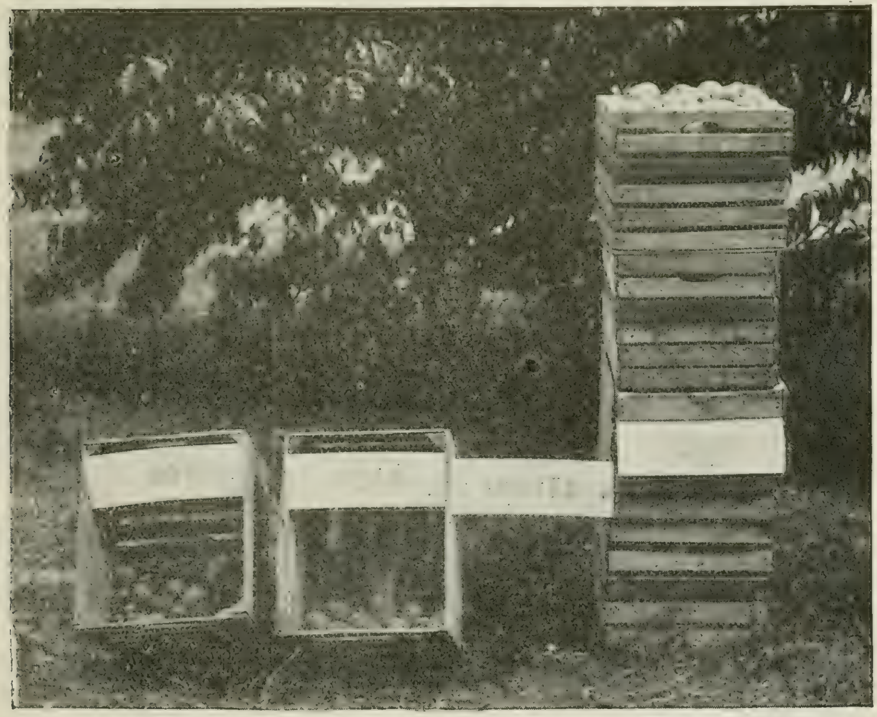

Fig. 11.—Fruit from dusted trees showing almost complete control of brown rot and peach scab.

For the late application no poison was used so the mixture contained: 85 per cent dusting sulphur, 15 per cent hydrated lime.

The use of hydrated lime in dusting materials for use on peaches has been generally recommended to prevent any possible injury by lead arsenate, but its greatest value probably is in improving the physical condition of the mixture so that it will spread evenly and cover more trees than a mixture containing no hydrated lime.

Applications. Two applications were made in this orchard. They were made at the periods and with the material here indicated.

1st. Just after last of "shucks" had dropped. The 75-15-10 mixture was used.

2nd. August 16. On Salway only. No lead arsenate was used. The trees were dusted from two directions and the work was done early in the morning when atmospheric conditions were favorable.

Weather Conditions. The entire season, until September, was very dry and unfavorable for the development of brown rot or peach scab; but after September 1st there was considerable rainy and "muggy" weather which was very favorable for the development of both diseases.

RESULTS.

Effect upon foliage and color of fruit. There was no indication of foliage injury at any time. The color of the fruit on dusted trees of Salway was apparently higher than on untreated trees.

Control of brown rot and peach scab. The results with Elberta were not conclusive as no appreciable amount of rot or scab developed even on the check trees. The quality of the Elbertas was excellent on both dusted and check trees.

With the Salways, the difference between dusted and check trees was very marked and the results of counts made when the fruit was picked is given in an accompanying table. The fruit from three representative dusted trees and three representative check trees was sorted into lots of sound, scabby and rotten fruit, and counts made of each lot.

TABLE 9.—BROWN ROT AND PEACH SCAB CONTROL, SALWAY PEACHES, 1921.

Treatment	Peach scab, per cent	Brown rot, per cent
Check	18	13
Dusted	0.7	3

These figures show that sulphur dust gave almost complete control of peach scab on Salways and favorable results in controlling brown rot while the fruit was still on the trees. The effect of the dust upon the keeping or holding quality of the fruit is discussed in the next paragraph.

Control of brown rot after harvest. Average samples of fruit from both dusted and check plots were taken and held for several days with the results shown in table 10.

TABLE 10.—HOLDING TEST ON SALWAY PEACHES, 1921.

Treatment	Picked	Brown rot—per cent		
		Sept. 26	Sept. 27	Sept. 28
Check	Sept. 24	15	60	100
Dusted	Sept. 24	0	2	10

The results were very good, especially when it is considered that the last application was made a full month before the fruit was picked.

EXPERIMENTS AT HART.

A series of experiments was conducted at Hart in the orchards of Geo. A. Hawley and Son and included peaches and plums. The varieties of plums were Lombard, Monarch and Grand Duke. The peaches were Wark, Hill's Chili and Gold Drop. This work was planned for the one purpose of determining if sulphur dust would improve the holding and shipping quality of the fruit by retarding the development of brown rot after harvest. The plots used for this work were distinct from the ones mentioned elsewhere in connection with experiments for the control of leaf-spot. All trees had had uniform treatment up to the time these experiments were begun. The previous treatment will be mentioned in connection with each experiment or group of experiments.

Monarch and Grand Duke Plums. Plots in orchards of each of these varieties were dusted on August 17 with a dusting mixture containing: 90 per cent dusting sulphur, 10 per cent hydrated lime.

This dusting was done under favorable conditions using about three-fourths of a pound of material per tree. Similar plots of each variety were left untreated at this time. All of the trees in both plots of the two varieties had been treated the same until this time. Two applications of dilute lime-sulphur spray had been made; the first just as the shucks were falling, about May 15, and the second the last week of June. There was no evidence of rot on any of these trees at harvest and, in fact, rot has not been noticeable in these orchards in recent years. There was considerable rainfall after August 17, when the dust was applied, which of course made conditions more favorable for rot development and tested the sticking quality of sulphur dust upon the waxy surface of the nearly mature plums. This particular point was given a more severe test on the Monarchs as there was a heavy rain after the Grand Dukes had been picked and before the Monarchs were ready. The treatment was given a severe test in another way on the Grand Dukes. The fruit was picked on August 22 and packed in baskets in the orchard, and paper pads were used under the covers. Before they were placed under shelter the baskets were thoroughly soaked by a sudden shower. The paper pads of course became wet and were still wet on August 30 when the fruit was examined. The results are shown in tables 11 and 12.

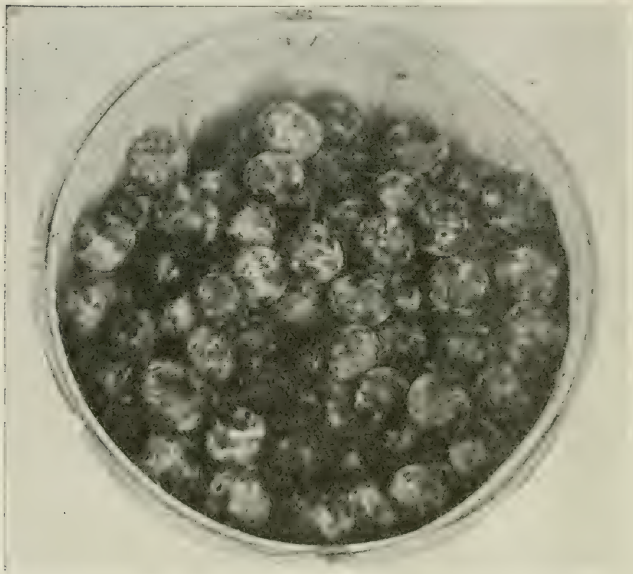

Fig. 12.—A basket of Monarch plums from trees dusted ten days before harvest. They were bright and in excellent condition ten days after harvest with no development of brown rot.

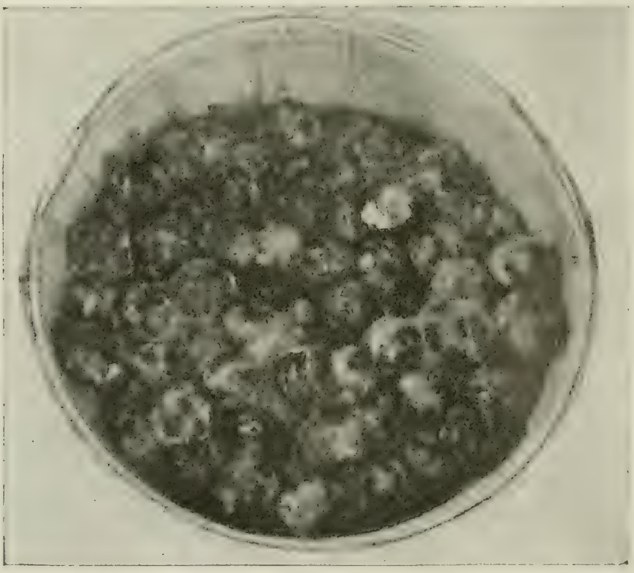

Fig. 13.—A basket of Monarch plums not dusted just before harvest. Ten days after harvest they were in such condition that they presented a very undesirable appearance when opened.

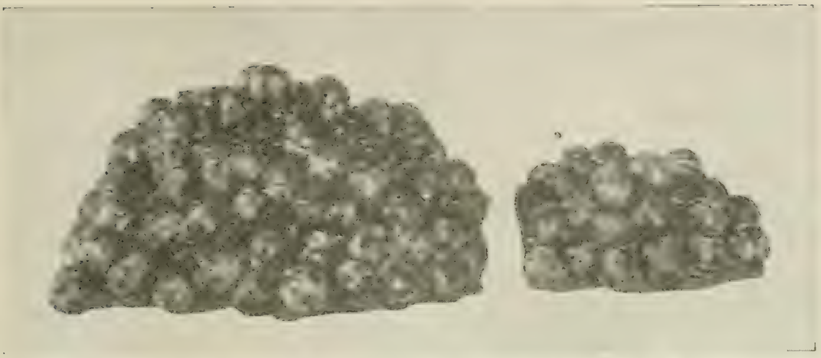

Fig. 14.—Monarch plums from trees not dusted just before harvest, showing the large proportion of rotten fruit (on left) twelve days after harvest.

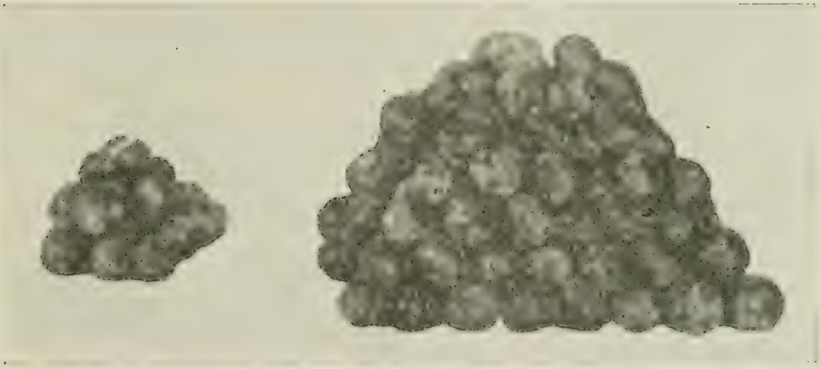

Fig. 15.—Monarch plums from trees dusted just before harvest showing the very small proportion of rotten fruit (on left) twelve days after harvest.

TABLE 11.—HOLDING TEST OF GRAND DUKE PLUMS, 1921.

Treatment	Dusted	Picked	Brown rot, Aug. 30, per cent
Check	0	Aug. 22	44
Dusted	Aug. 17	Aug. 22	6

TABLE 12.—HOLDING TEST OF MONARCH PLUMS, 1921.

Treatment	Dusted	Picked	Brown rot—per cent		
			Sept. 7	Sept. 10	Sept. 12
Check	0	Aug. 30	1	13	78
Dusted	Aug. 17	Aug. 30	0	2	7

The Grand Dukes were held at Hart for examination but the Monarchs were shipped to East Lansing and were accidentally placed in cold storage with some other fruit and were not removed for three days. This accounts for the longer period between the time they were picked and when they began to decay.

Wark Peaches. Wark is an early ripening peach which, like some other varieties ripening at the same season, is very susceptible to brown rot. Mr. Hawley has usually experienced difficulty in handling these peaches as they would be picked, apparently in good condition, but would rot so quickly that he was frequently unable to get them shipped before they had badly decayed. The orchard contains about two hundred trees and was divided into three plots.

1. Check plot. No treatment. It contained two rows of ten trees each.
2. Dusted. One application, July 28. This plot was made up of about 50 trees.
3. Dusted. Two applications. July 5 and July 28. This plot contained about 130 trees.

The trees were dusted at each application from two directions using about ¾ pound of material per tree. This orchard had no summer application of either dusting or spraying materials. The dust used contained 85 per cent dusting sulphur, 15 per cent hydrated lime.

RESULTS.

Control of brown rot before harvest. Careful observations were made by Mr. Monroe Hawley when the fruit was picked. The fruit on all the trees in both dusted plots was practically free from brown rot at this time, but on the check trees there was a small but noticeable amount of it. The development of brown rot on the trees was probably greatly retarded by the dry weather which had prevailed in this district nearly all summer.

Control of brown rot after harvest. When the fruit was picked average samples were taken from each plot, packed and shipped to East Lansing and examined at intervals with the results shown in table 13.

TABLE 13.—HOLDING TEST OF WARK PEACHES, 1921.

Treatment	Dusted	Picked	Brown rot—per cent.		
			Aug. 10	Aug. 12	Aug. 13
Check	0	Aug. 9	5	38	82
Dusted	July 28	Aug. 9	0	12	....
Dusted	July 5, 28	Aug. 9	0	0	10

The fruit from the plot dusted once only was found to be considerably riper than that from the other plots so that on August 12 it was so ripe that it had to be discarded. This condition would, of course, make the control of brown rot more difficult. It may have been also due to the fact that the fruit did not receive the first application. The difference in the condition on August 13, of the fruit from the check plot and the plot dusted twice, was marked. The fruit from the check plot was almost a total loss while that from the dusted plot was in good condition.

Hill's Chili and Gold Drop Peaches. Two blocks of Hill's Chili and one of Gold Drop were used in an experimental way. One block of Chili trees consisted of large, mature trees which were fillers in an apple orchard. The other was a block of about 75 young bearing trees. The Gold Drops were also mature trees set as fillers in an apple orchard. Gold Drop is a variety not usually considered very susceptible to brown rot, but Hill's Chili, a susceptible variety, usually rotted badly in these orchards in previous years.

No early summer applications of dusting or spraying materials were made on any of these trees. The Hill's Chili trees received an application of sulphur dust on July 28. All trees were dusted, no check or untreated plot being left at this time. The Gold Drop trees did not receive this application. When the special application was made on August 31, check plots were left untreated in each block of trees. Care was taken that these check plots were not located in positions that were more favorable to rot development than the dusted portions of the orchards. Where there was much variation in elevation, the check plots were located on the high ground so that they would have the advantage of better air circulation.

On August 31, when the dusting was done, conditions were ideal for such work. The trees were wet from rain which had fallen during the night and remained in this condition most of the forenoon. The dusting was finished by 10:00 A. M. and there had been no wind to interfere. All trees were dusted from two directions.

RESULTS.

Control of brown rot before harvest. On all Chili trees which were well dusted, there was very little development of rot previous to the time the fruit was picked. On the check trees of the young orchard the fruit rotted badly, while on the check trees of the old orchard the presence of rot was indicated largely by the fruit which dropped. The rot usually developed near the stem end of the fruit and thus caused it to drop before the entire peach was decayed. By the time the first peaches were ready to pick, there was much fruit on the

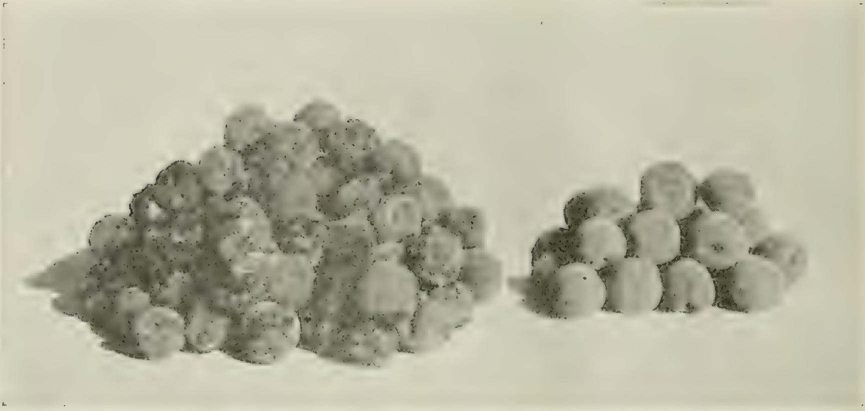

Fig. 16.—Wark peaches from untreated trees showing the proportion of sound peaches (on right) and those affected with brown rot (on left) four days after harvest.

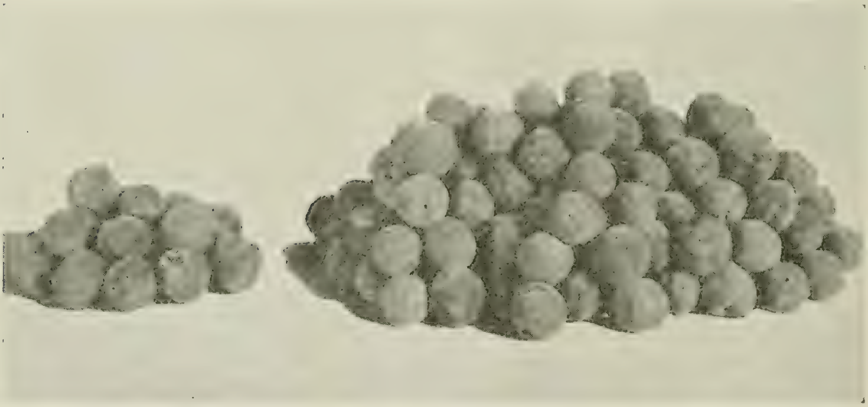

Fig. 17.—Wark peaches from trees dusted twice shortly before harvest with sulphur dust, showing the very small proportion affected by brown rot (on left) after four days.

ground under the check trees but practically none under dusted trees. The first fruit was picked from these trees on September 9 and Mr. Hawley reported on September 21 that there was still some fruit on the dusted trees but none on the check trees. There was little evidence of rot on the Gold Drops previous to harvest on either the dusted or check trees.

Control of brown rot after harvest. The fruit for "holding" tests was picked on September 9. . The sample for each plot was taken from several trees so as to represent an average condition. No peaches from the check trees were used which showed any rot when picked. The results of the "holding" tests are given in table 14.

TABLE 14.—HOLDING TESTS OF HILL'S CHILI AND GOLD DROP PEACHES, 1921.

Variety	Treatment	Dusted	Picked	Brown rot, Sept. 13, per cent
Chili (young)	Check	0	Sept. 9	86
	Dusted	Aug. 31	Sept. 9	28
Chili (old)	Check	0	Sept. 9	64
	Dusted	Aug. 31	Sept. 9	35
Gold Drop	Check	0	Sept. 9	30
	Dusted	Aug. 31	Sept. 9	9

The amount of rot on the dusted fruit of the Chili was somewhat higher than with other varieties but the results obtained from the late application of dust were quite satisfactory, especially when it is considered that this variety is highly susceptible to rot and that weather conditions were very favorable for rot development.

SUMMARY OF RESULTS OF HOLDING TESTS.

The results of the several experiments may be better compared if brought together as in table 15.

TABLE 15.—SUMMARY OF RESULTS OF HOLDING TESTS.

Variety	Time held	Final condition Brown rot, per cent.	
		Check	Dusted
Lombard (1920)*	6 days	90	5
Grand Duke	6 days	44	6
Monarch	12 days	78	7
Wark	4 days	82	10
Chili (young)	4 days	86	28
Chili (old)	4 days	64	35
Gold Drop	4 days	30	9
Salway	4 days	100	10

*The percentages for this variety are only approximate. The plot indicated here as the "check" is the one which was sprayed throughout the summer but was not given the late application of sulphur dust.

The late application of sulphur dust or of any other fungicide to improve the holding and shipping quality of the fruit should be considered as a supplement to the regular summer schedule and not a substitute for it. The number of earlier applications needed will depend somewhat upon the kinds and varieties of fruit being grown. Varieties which are known to be susceptible to brown rot should be thoroughly sprayed or dusted during the summer so as to insure a crop in good condition at harvest.

OTHER EXPERIMENTS WITH PEACHES.

Experiment at South Haven. In 1920 at South Haven on the H. E. Hawley farm an extensive peach dusting experiment was carried through in an orchard which contained blocks of Gold Drop, Smock and Elberta. The materials used were sulphur dust and dehydrated copper sulphate dust but no conclusive results were obtained because there was no development of any insect or fungus injury even on the check plots. There was no foliage injury by either of the dusting materials.

EXPERIMENTS FOR THE CONTROL OF THE PEACH TREE BORER WITH PARA-DICHLOROBENZENE.

Para-dichlorobenzene has been used experimentally in several orchards during 1920 and 1921. This is a material which has been used in an experimental way for several years and more recently has been used in a practical way by many growers in certain districts. It is obtainable in a crystalline

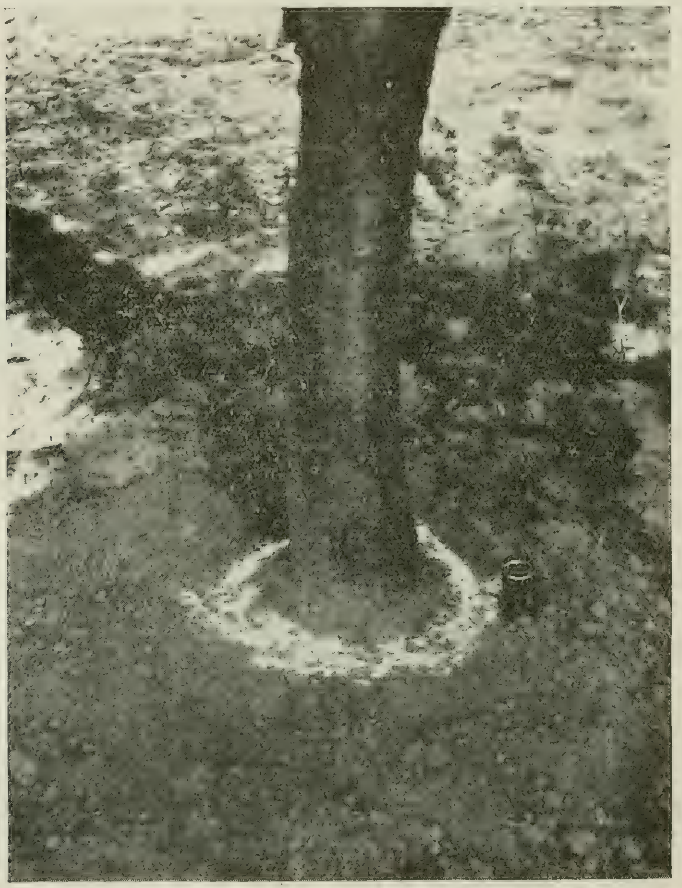

Fig. 18.—Soil leveled and para-dichlorobenzene applied in a band about 1½ inches wide and an equal distance from trunk. Small can used for measuring material is shown at the right of tree.

or granular form and when exposed at a temperature of 55 to 60 degrees or higher, it vaporizes to a gas which is about six times heavier than air. The crystals, which are placed around the base of a peach tree, vaporize into this heavy gas which penetrates through the soil into the borer tunnels and acts as a poison to the borer.

The method of application used in all the experiments here reported was as follows. The soil around the base of the tree was made reasonably level and smooth without digging it up. Any grass or weeds around the tree were removed and excessive exudations of gum close to the ground were also removed. When there were any indications that there were borers five or six inches above the normal level of the soil, the soil level was raised to that point.

The para-dichlorobenzene was then spread around the tree in an even band, about 1½ inches wide, and at about the same distance from the tree. The material had previously been put through a wire screen of about 10-mesh fineness (ordinary window screening has about 10 meshes to the inch) to break up any lumps. A mound of soil four to six inches deep was then placed over the para-dichlorobenzene and packed lightly with the back of a shovel.

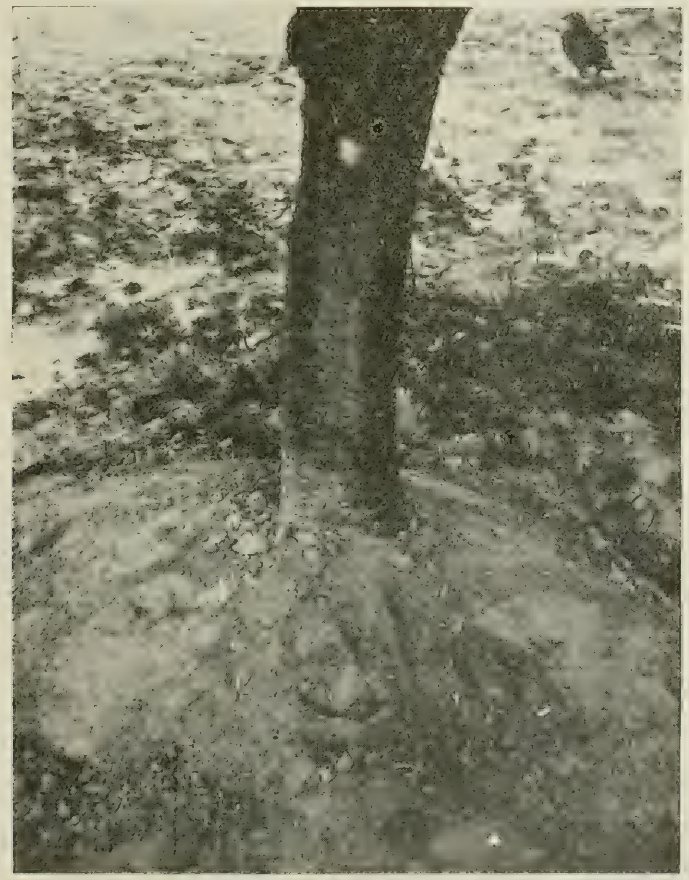

Fig. 19.—A mound of soil 4 to 5 inches high placed around tree and over the para-dichlorobenzene.

EXPERIMENT AT SAUGATUCK.

The first test of this material was begun in the fall of 1920 at Saugatuck on the farm of Mr. James Boyce. The trees were six years old and grew in very sandy soil. The variety was Banner. The borer larvae had not been dug from the trees that season.

Application. The para-dichlorobenzene was applied to the trees on September 8, 1920, at the rate of ¾ to 1 ounce per tree. The amount was varied according to the size of the tree. Fourteen rows of thirteen trees each were included in the experiment and three of these rows were left untreated as checks. The treated and check rows were distributed as follows:

Row 1 to 5. Treated.
Row 6. Check.
Rows 7 to 9. Treated.
Rows 10 to 11. Check.
Rows 12 to 14. Treated.

Results. Certain rows of treated and untreated trees were examined on October 28, 1920, and others on June 7, 1921. The results are given table 16.

TABLE 16.—PEACH BORER CONTROL AT SAUGATUCK, 1920-21.

Plot	Number trees examined	When examined	Borers alive	Average per tree
Treated	77	Oct., 1920	2	.025
Check	23	Oct., 1920	30	1.3
Treated	26	June, 1921	1	.038
Check	13	June, 1921	25	1.9
Treated—total	103		3	.029
Check—total	36		55	1.52

Percentage of control—98.2 per cent.

EXPERIMENT AT SOUTH HAVEN.

Another similar experiment was begun at South Haven in 1921 on the farm of Mr. C. C. Chesebro. The trees were fourteen years old and of Kalamazoo, Gold Drop and Salway varieties. The para-dichlorobenzene was applied on September 1 at the rate of 1 ounce per tree and in the way described above. The trees were examined on October 12 and with the results given in table 17.

TABLE 17.—PEACH BORER CONTROL AT SOUTH HAVEN, 1921.

Plot	Number trees examined	Borers alive	Average per tree
Treated	67	2	.029
Check	46	13	.28

Percentage of control—90 per cent.

The percentage of control refers to the effect of the para-dichlorobenzene upon borers occurring below the surface of the mound placed around the tree when treated. In this orchard the infestation was largely on the trunk above the level of the mounds so that a large proportion of the borers were not subject to the effects of the material. The trunks of these trees were rough and had many wounds and dead places in the bark and it was around such places that many of the borers were found. The lesser peach-tree borer usually prefers to work on older trees with rough bark and around wounds but the species working on these trees was not determined.

EXPERIMENT AT FENNVILLE.

Another experiment was begun in 1921 at Fennville on the Wadsworth Brothers' farm. This work was on trees in two separate blocks, one of six-year-old Elberta and the other of older trees of several varieties but mostly New Prolific. The trees of the younger block were in good condition and generally had smooth, sound trunks. The soil there was quite sandy. In the older block the soil was much heavier and the trees had much rough bark with many old wounds on the trunks.

Application. The para-dichlorobenzene was applied in this orchard on September 2 in the usual way and at the rate of ¾ to 1 ounce per tree. About 125 trees were treated and alternate rows left as checks in the Elberta block, and an equal number were treated in the block of older trees with checks left in the same way.

Results. A portion of the trees in each block were examined on October 4 and 5. The borers were dug only from that part of each treated tree which was below the top of the mound placed around them and from comparable parts of the untreated trees. The record of results obtained in each block is shown in tables 18 and 19.

TABLE 18.—PEACH BORER CONTROL ON ELBERTA AT FENNVILLE, 1921.

Plot	Number trees examined	Borers alive	Average per tree
Treated	43	3	.07
Check	49	177	3.61

Percentage of control—98.1 per cent.

TABLE 19.—PEACH BORER CONTROL ON OLDER TREES AT FENNVILLE, 1921.

Plot	Number trees examined	Borers alive	Average per tree
Treated	17	0	0
Check	19	17	.9

Percentage of control—100 per cent.

In the older trees the control of borers which were in a position to be affected by the para-dichlorobenzene was perfect, but this does not mean that a large percentage of the total number of borers actually on the tree was killed. These trees had trunks with rough bark and many old wounds and it was around these wounds high on the trunks and in the crotches that most of the borers were present. The check trees, as shown in the table, had a very low infestation in the lower part of the trunks and in the crowns.

SUMMARY.

In all these experiments, the borers which were in such a position that they could be affected by the para-dichlorobenzene, were effectively controlled. On trees with smooth trunks and few wounds, most of the borers were low enough to be effectively treated but on older trees with rough bark and many wounds along the trunks and in the crotches, a large proportion of the borers were too high to be subject to this treatment.

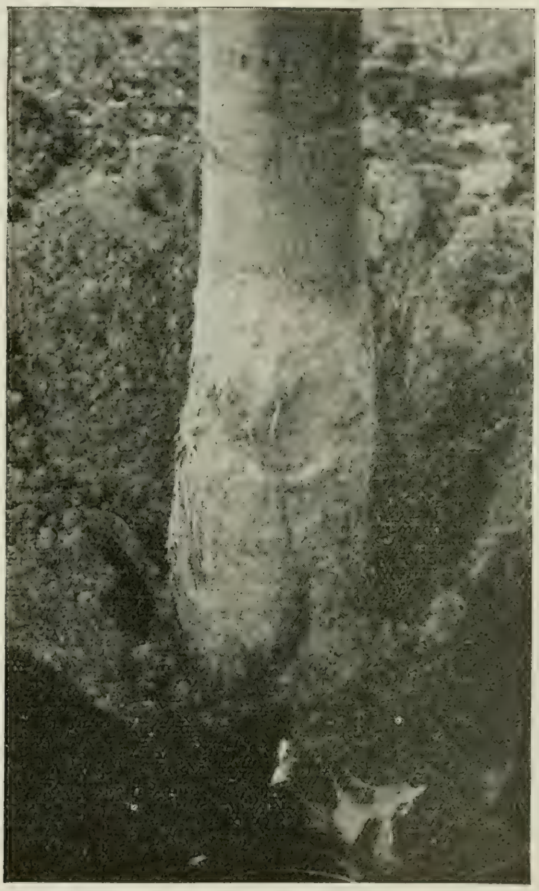

Fig. 20.—A tree which has been treated with para-dichlorobenzene and the borers controlled without digging or "worming" them out. The tree is left in sound condition.

Injury to trees. There has been no evidence of injury to treated trees by para-dichlorobenzene in any of the experimental orchards. The trees were all six years of age or older. Trees younger than six years, according to the results of other experiments,* cannot be safely treated in the usual way and should not be so treated until satisfactory methods are determined.

Mechanical injury to trees. The unavoidable injury to the bark of trees caused by the operation of digging out the borers is serious, especially on badly infested trees. In contrast to this, the crowns of trees where the borers are controlled by this method are maintained in sound condition.

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*Blakeslee, E. B., U. S. Dept. Agr. Bul. 796, and Peterson, Alvah, New Jersey Agr. Exp. Sta. Circ. 126.

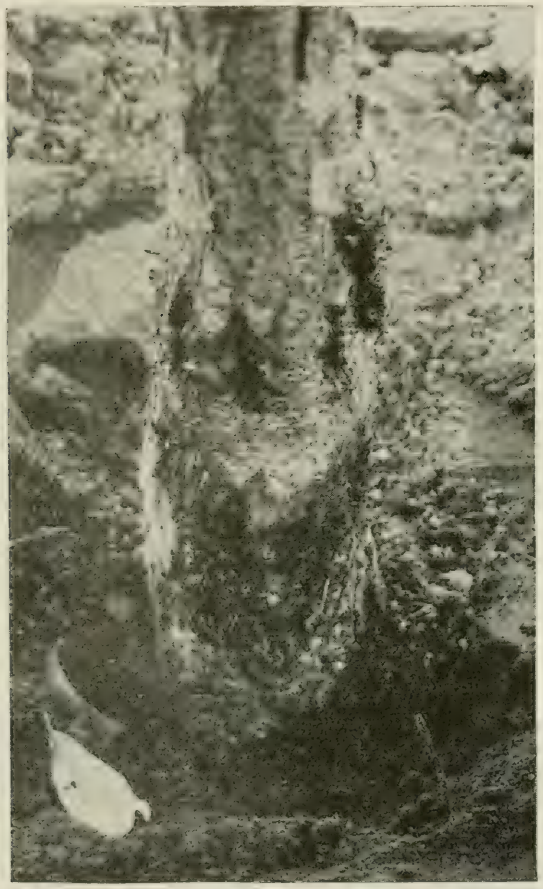

Fig. 21.—A tree from which several borers were removed by the usual "worming" process. The bark was severely injured.

Leaf-Spot Control on Cherries and Plums.

EXPERIMENTS WITH CHERRIES.

Summary of Previous Experiments. Work with cherries was carried on in 1919 and was reported in Special Bulletin No. 102. Briefly, the results were as follows. With Montmorency the results were not conclusive because of absence of leaf spot in the untreated trees, but with English Morello the check trees were defoliated by September. Trees sprayed with lime-sulphur held their foliage in good condition until late in September and then the development of leaf-spot was only very slight. Trees dusted with sulphur dust were affected by leaf spot early in August and were badly defoliated by the middle of September.

EXPERIMENTS IN 1920 AND 1921.

During the seasons of 1920 and 1921, extensive experiments for the control of leaf-spot were conducted at Traverse City on the Titus Brothers' farm. Two orchards were used in this work. One was Montmorency with trees nine years old at the beginning of the work. The other orchard was English Morello, one-half the trees being nine years old and the other half twenty-one years old at the time the work was begun. These orchards had been dusted entirely for two or three years previous to 1920 and the control of leaf-spot had, in one year in particular, been unsatisfactory. Thorough cultivation is practised in these orchards, which is usually considered important in the control of leaf-spot if done early so as to cover the old leaves before infection occurs.

Object of the experiments. This work was carried on in order to get all information possible concerning the comparative value of the following materials:

1. Lime-sulphur solution.
2. Bordeaux mixture.
3. Sulphur dust.
4. Dehydrated copper sulphate dust.

Arrangement of the plots. Each orchard was divided into four large plots, one for each material noted, and one small plot which was left untreated as a check. This check plot was so located that very little, if any, dust drifted on to it. The plots were essentially the same for both years except that different trees were used each year for the check plots. Each of the dusted plots contained from 80 to 100 trees, the sprayed plots from 40 to 60 trees, and the check plots 8 to 10 trees.

Materials used. The same materials were used both seasons but at different strengths or proportions. The exact formulae for each year are given in table 20.

TABLE 20.—MATERIALS USED IN CHERRY DUSTING AND SPRAYING EXPERIMENTS.

Material	1920	1921
Lime-sulphur	1¼ gal. in 50	1½ gal. in 50.
Bordeaux*	4—6—50	4—7—50.
Sulphur dust	90—10	80—10—10.
Dehydrated copper sulphate dust	15 per cent dehydrated copper sulphate.	20 per cent dehydrated copper sulphate.

*Hydrated lime was used and at the rates indicated.

The rate of dilution for lime-sulphur solution was increased from 1¼ to 1½ gallons in 50 as the weaker dilution did not give complete control in 1920. Bordeaux mixture was made in 1920 with 6 pounds hydrated lime in 50 but was increased in 1921 to 7 pounds in 50 so as to more surely counteract any tendency to foliage injury. Most of the sulphur dust used in 1920 was of the 90-10 mixture (when poison was used), but in 1921 the 80-10-10 mixture was used. This mixture contains 10 per cent of hydrated lime which insures better distribution. The strength of the copper sulphate dust was increased from 15 per cent in 1920 to 20 per cent in 1921 and further, 10 per cent of talc was added to the mixture so as to improve its physical condition.

Application. All dust was applied with a large power duster and the duster was usually drawn by a tractor. In 1920 the work was usually performed under satisfactory atmospheric conditions while in 1921 conditions were always favorable when the work was done, most of it being done in the evening or early morning. The trees were dusted from two directions at each application. A power sprayer which maintained a pressure of 225 to 250 pounds was used for all spraying operations and the material was applied to the trees with a spray gun.

Applications were made at the periods here indicated:

ENGLISH MORELLO.

		1920	1921
1st.	Just before blossoms opened	Dusts and sprays	Dusts and sprays
2nd.	Just after blossoms fell	" " "	" " "
3rd.	Two weeks after the second application	" " "	" " "
4th.	About July 1	" " "	" " "
5th.	After harvest	" " "	" " "

MONTMORENCY.

		1920	1921
1st.	Just after blossoms fell	Dusts and sprays	Dusts and sprays
2nd.	Two weeks after first application	" " "	" " "
3rd.	About July 1	Dusts only	Neither
4th.	After harvest	" "	Neither

Lead arsenate was used on both dusted and sprayed plots in the two applications after blossoms had fallen.

The pre-blossom application was not made on the Montmorencies but was made on the English Morellos as they bloom later and are much more susceptible to leaf-spot. In 1920 dust only was used at the July application on the Montmorencies as the fruit was so nearly ripe that the spraying materials would have stained it. In 1921 the same conditions prevailed and as no leaf-spot had developed even on the checks, neither the dust nor spray was applied. The "after-harvest" application of both materials was omitted on this variety for the same reason.

Weather conditions. During the season of 1920 there was so much rainfall that conditions were quite favorable for leaf-spot development. There was a bad infection period in June and another later in the summer. In 1921 the early part of the season was very dry and unfavorable for leaf-spot but was more favorable from the middle of July until September.

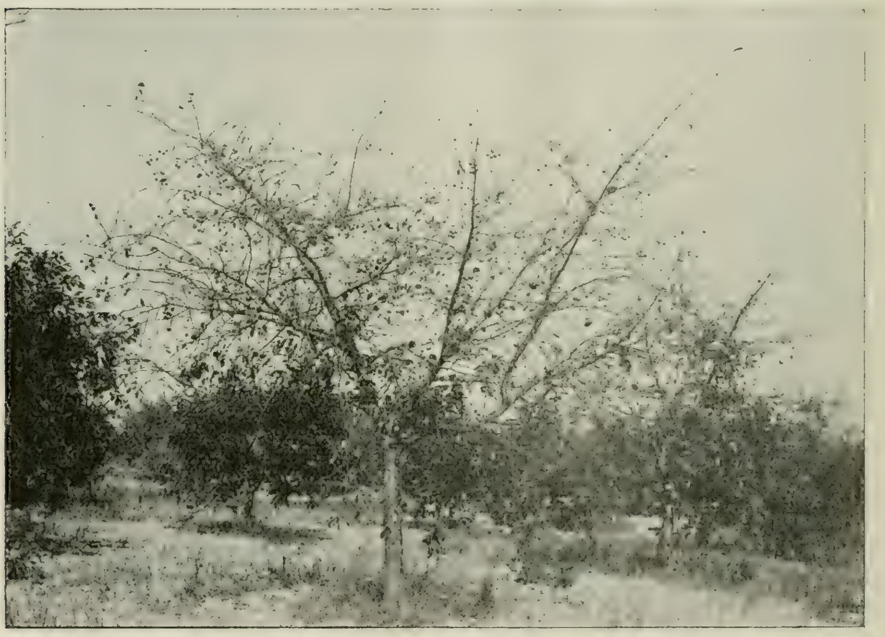

Fig. 22.—An English Morello tree from check plot showing the degree of defoliation which occurred by early August in 1920. In 1921 defoliation to a similar extent developed by September.

RESULTS.

Leaf-Spot Control. In the season of 1920, leaf-spot never became serious on the Montmorency trees, even the untreated ones showing no serious infection. These trees lost some foliage but not a noticeable amount. At the end of the season, the dusted plots showed some leaf-spot in the early stages but it did not cause any leaves to drop. The lime-sulphur plot showed some leaf-spot a little earlier in the season. In 1921 results with Montmorency were even less conclusive than in 1920 as no appreciable amount of leaf-spot developed even on the check trees.

With English Morello, however, the development of leaf-spot was very pronounced on the check trees both years. In 1920 there was a serious defoliation on the checks by July, probably half the leaves being lost. Early in August the foliage was quite thin and by September the trees were entirely defoliated. Considering the season as a whole, bordeaux ranked highest in leaf-spot control but it caused the loss of many leaves as noted below. Lime-sulphur ranked second and the two dusts a little lower than the lime-sulphur. The control in the bordeaux plot was not perfect and the other plots showed an increasing amount of leaf-spot in the order named above. There was little difference between the two dusted plots but sulphur dust gave slightly better results than copper sulphate dust.

In 1921 the Morello check trees did not show any serious development of leaf-spot until August but by September these trees were practically defoliated. The control of leaf-spot by all materials was almost perfect but there was a difference in the effect upon the fruit and foliage as noted in the next paragraph. The better results with the dusts in 1921 may be due to the fact that the dusting was all done under favorable conditions. Other factors to be considered are the different strengths of dusting materials and the weather which was less favorable to leaf-spot development than in 1920.

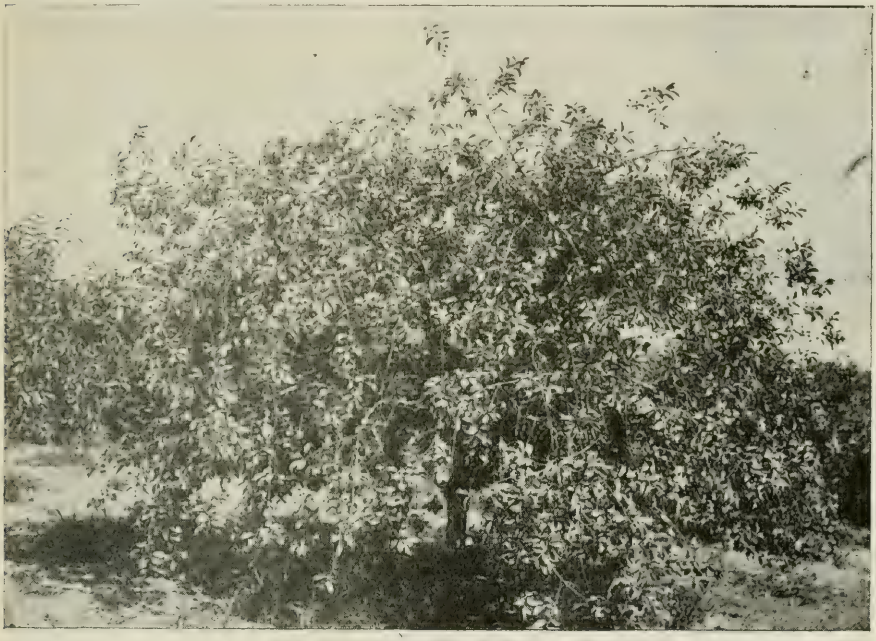

Fig. 23.—An English Morello tree from the bordeaux plot in 1920. All sprayed and dusted trees in 1921 were in even better condition than this at the end of the season.

Effect upon foliage and fruit. Bordeaux in 1920 caused serious foliage injury on English Morello and to a lesser degree on Montmorency. This injury was of the yellow leaf type and caused quite heavy defoliation, especially on the English Morello trees. This injury developed just after a period of several days marked by dense fogs followed by high temperatures.

Such a condition is recognized as being ideal for the development of the type of injury found. The foliage of the trees in the lime-sulphur plot showed no injury but was usually not so bright in appearance as in the other plots. The foliage of trees in both dusted plots was in excellent physical condition.

In 1921 there was no foliage injury and, in physical condition of foliage, the dusted plots ranked first, the bordeaux plot second, and the lime-sulphur plot a little below the bordeaux plot.

An unusual effect of bordeaux upon the fruit of the English Morello developed in 1921. The fruit in this plot was much smaller in size than on any other plot. A report of the same or a similar trouble has recently come from the Northwest.* The trouble there was evidently caused by the use of strongly alkaline spraying materials and was probably due to the same cause here. So little is known about the trouble at the present time that no definite statement can be made regarding it.

Control of Brown Rot and Slugs. There was some brown-rot on the Montmorency check in 1920, but it was completely controlled on all dusted and sprayed plots. There was also considerable injury by slugs in 1920 to the foliage of the check trees of both varieties, but none of this injury was found on dusted or sprayed trees of either variety.

EXPERIMENTS WITH PLUMS.

Summary of previous experiments. The only earlier work on plums which will be mentioned includes two experiments, one on Japanese and native plums in 1918 and another on Japanese plums in 1919. The foliage of such varieties is very susceptible to injury by most of the ordinary spraying materials and one object of these experiments was to determine if sulphur dust would injure the foliage and the results indicated very plainly that it could be used with safety on Japanese and native varieties of plums.

EXPERIMENTS IN 1920 AND 1921.

Experiment at South Haven. At South Haven in 1920 on the H. E. Hawley farm, a comparative test of lime-sulphur, sulphur dust and copper sulphate dust was made. The variety was Lombard. It was a general test for the control of leaf-spot, curculio and brown rot but only leaf-spot will be considered here. The results were not conclusive as the foliage of the check trees showed no leaf-spot at any time during the summer and the foliage of the trees in all plots was in excellent physical condition at all times but the foliage of dusted trees was slightly better than that of the sprayed trees.

Experiment at Hart. At Hart in 1921 on the Geo. A. Hawley farm, a comparison was made of dusting and spraying for the control of leaf-spot, brown rot and curculio on plums. This work was done in three separate orchards and included five varieties, viz., Monarch, Grand Duke, Arch Duke, Lombard and Bradshaw. The materials used were sulphur dust and lime-sulphur.

A detailed description and report of the experiment will not be given as the results were not conclusive because of the absence or small amount of injury by any of the troubles mentioned. Late applications of sulphur dust were made on other plots for the control of any brown rot which might develop after harvest and a detailed report of that work will be found in another part of this bulletin.

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*D. F. Fisher, Effect of Alkaline Sprays on Sweet Cherries, Journal of American Society for Horticultural Science, Oct. 1921.

DRY LIME SULPHURS AND SIMILAR MATERIALS.

EXPERIMENTS TO DETERMINE THEIR EFFICIENCY IN CONTROLLING APPLE SCAB AND PEACH LEAF-CURL.

EXPERIMENTS FOR THE CONTROL OF APPLE SCAB.

Comparative tests of dry lime-sulphurs and similar materials with lime-sulphur solution have been made for several years and the results of all work done previous to 1921 have been published.* A summary of that work is included in this report.

Experiment in 1921. A comparative test of dry lime-sulphurs with lime-sulphur solution as summer sprays was made on Duchess apples at South Haven in 1921. This work was done in the Harriman orchard. The trees were about ten years old and had not been well sprayed in previous years.

Materials and applications. Standard lime-sulphur solution and two brands of dry lime-sulphur were used as follows:

1. Lime-sulphur solution, 1¼ gal. in 50.
2. Dow dry lime-sulphur, 4 lbs. in 50.
3. Sherwin-Williams dry lime-sulphur, 4 lbs. in 50.
4. Sherwin-Williams dry lime-sulphur, 6 lbs. in 50.
5. Check plot. No treatment.

Lead arsenate was used with all materials.
Three applications were made as follows:

1st. Pink application; when blossom buds had separated in the clusters.
2nd. Calyx application; just after the petals had dropped.
3rd. Two weeks after calyx application.

Weather conditions. The season as a whole was quite dry, except very early just as the blossom clusters were expanding. There was so much rain during this period that it was impossible to make the "pre-pink" application.

RESULTS.

The fruit from all the trees in each plot was sorted at harvest into two classes, "scabby" and "clean", and the results are given in table 21.

TABLE 21.—RESULTS WITH DRY LIME-SULPHURS ON DUCHESS, 1921.

Material	Number apples examined	Scabby, per cent
Lime-sulphur solution, 1¼ gallons in 50	3617	11
Dow dry lime-sulphur, 4 pounds in 50	1665	17
Sherwin-Williams dry lime-sulphur, 4 pounds in 50	1151	27
Sherwin-Williams dry lime-sulphur, 6 pounds in 50	726	29
Check. No treatment	927	50

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*Special Bulletin 102 and Quarterly Bulletin, November 1920.

The percentage of scab given in this table include that caused by infection occuring either before or after the pink or cluster application, although the "pre-pink" application was not made because of unfavorable weather conditions. These figures show that the dry lime-sulphurs did not give as good control of scab as the solution.

Summary of All Experiments with Dry Lime-sulphurs. A brief summary of all experiments with dry lime-sulphurs and similar materials should be of value and is shown in table 22.

TABLE 22.—SUMMARY OF RESULTS WITH DRY LIME-SULPHURS.

Material	Year	Variety	Scabby, per cent
Lime-sulphur solution, 1¼ gal., in 50 gal.	1917	Spy	21
	1919	Duchess	15
	1920	Duchess	24
	1921	Duchess	11
		Average	18
Sherwin-Williams dry lime-sulphur, 3 to 4 lbs. in 50 gal.	1917	Spy	31
	1919	Duchess	31
	1920	Duchess	60
	1921	Duchess	27
		Average	37
Sherwin-Williams dry lime-sulphur, 5½ to 6 lbs. to 50 gal.	1919	Duchess	22
	1920	Duchess	63
	1921	Duchess	29
		Average	38
Dow dry lime-sulphur, 3 to 4 lbs. in 50 gal.	1919	Duchess	37
	1921	Duchess	17
		Average	27
Dow dry lime-sulphur, 5½ lbs. in 50 gal.	1919	Duchess	35
		Average	35
B. T. S., 7 lbs. in 50 gal.	1919	Duchess	25
		Average	25
Unsprayed	1917	Spy	97
	1919	Duchess	62
	1920	Duchess	95
	1921	Duchess	50
		Average	76

This summary shows that the standard lime-sulphur solution has given in every experiment better control of apple scab than any of the dry lime-sulphurs or similar materials.

DUSTING FOR THE CONTROL OF PEACH LEAF-CURL.

A test was made at Saugatuck in the spring of 1919 to determine if leaf-curl can be controlled by the use of dusting materials. The results obtained from the use of sulphur dust and soluble sulphur dust were entirely unsatisfactory as neither gave any degree of control. This experiment has been reported in detail in Special Bulletin No. 102.

Another similar test was made in 1920 at South Haven on the farm of Mr. Jas. Nicol. The trees were mature and the variety was Marshall's Late.

Materials and application. Two plots were dusted, two sprayed and one left untreated as a check. The materials used were as follows:

1. Lime-sulphur solution, 2½ gal. in 50.
2. Lime-sulphur solution, 6¼ gal. in 50.
3. Soluble Sulphur Dust (Niagara).
4. Bordeaux dust (Niagara).
5. Check. No treatment.

The materials were all applied during the last week of March and the trees were entirely dormant at that time.

Results. Weather conditions were not most favorable for leaf-curl development and the disease did not develop seriously even on the check trees, but there was sufficient infection to give a comparison. The trees were examined at different times, the last of which was early in June when the following comparisons were made.

The trees in both sprayed plots were practically free from curled leaves. The trees in both dusted plots showed some leaf-curl but not to a large degree. The check trees had many curled leaves but little defoliation had occurred.

The results of this experiment are not conclusive if considered alone but when considered with the results obtained in 1919, the conclusion must be made that satisfactory control of peach leaf-curl has not been obtained with dusts.

Lime-sulphur solution, 2½-50, gave results in this experiment equal to the results obtained from the use of lime-sulphur solution, 6¼-50.

GRAPE DUSTING EXPERIMENTS.

Dusting experiments with grapes have been in progress during the seasons of 1920 and 1921 but no conclusive results have been obtained from this work. Dusting materials have been used for the control of black rot, the grape berry moth and grape leaf-hoppers, but it will be necessary to continue this work before any definite statements can be made as to the comparative value of the dusting and spraying methods for the control of grape pests.

POTATO DUSTING EXPERIMENTS.

Potato dusting experiments were begun in 1920 and continued in an extensive way in 1921. Work was carried on at Paw Paw, Van Buren County; Manton, Wexford County; Alba, Antrim County; Boyne City, Charlevoix County, and Levering, Emmett County. Power dusters were used at some places and hand dusters at others. A detailed statement concerning the experiments and the results obtained will not be included in this report but the work will be continued and a report made later.

Special Bulletin No. 116.

FOREWORD

The purpose of this bulletin is to bring together under one cover, as far as possible, all available data on the agriculture of the Upper Peninsula of Michigan. This portion of the State is undeveloped agriculturally, and it is important that all facts pertaining to this essential industry be compiled in a convenient form for the business man, the teacher, the prospective settler, and the farmer already engaged in agriculture.

The data presented, unless otherwise stated, were taken from the Fourteenth United States Census Report (1920). The balance of the information was obtained from the experimental data of the Upper Peninsula Experiment Station, at Chatham, Michigan; from the United States Weather Bureau; and from observations and experiments conducted by county agricultural agents, extension specialists, or other representatives of the Michigan Agricultural College.

The information is offered for the purpose of stimulating a more general and complete understanding of the Upper Peninsula and its agricultural development and possibilities.

J. W. WESTON

THE AGRICULTURE OF THE UPPER PENINSULA.

ITS PRESENT DEVELOPMENT AND POSSIBILITIES.

BY J. W. WESTON, D. L. MCMILLAN AND G. W. PUTNAM.

Conditions which make for comfortable and profitable living are present in Michigan's Upper Peninsula. The vigorous interests of a developing country are combined with good markets, fine roads, good schools and churches, excellent railroad facilities, and a large acreage of fertile land.

The summer climate of the Upper Peninsula is famous the country over, while those who know the section in the winter claim that this invigorating season, with its uniform climate and its winter sports, is exceptionally healthful and pleasant. The climatic conditions also favor the production of a wide range of crops and livestock. The mean annual temperature is about 40 degrees Fahrenheit, and the annual average rainfall is about 30 inches. A large part of this comes in the growing season, 18 to 25 inches falling from May 1 to October 1.

An area of more than ten million acres is included in the Upper Peninsula. From Menominee on the south to Keweenaw Point on the north is a distance of 173 miles, while the territory extends 337 miles from the eastern end of Chippewa county to the state line on the west. It lies in the 46th Meridian and has approximately 1,000 miles of coast on the Great Lakes. Its elevation varies from 580 feet on the southern slope to 2,023 feet on the highest point in the Porcupine Mountains.

Fig. 2. A general view of the Agricultural Experiment Station located at Chatham, Mich.

Extensive areas of fertile soils, including cleared, cut-over, and timber land, are to be found in the upper country. Good yields of many crops are produced in Cloverland, and crop production, although extensive, is only in its infancy. The present development is sufficient, however, to forecast a great future for the region.

The Upper Peninsula is essentially a livestock country, with dairying now developed to a greater extent than any other phase of the farming industry. A few of the best herds of the country have been produced in this part of Michigan.

Potatoes, celery, and vegetables grown in this section have a quality and flavor which is unexcelled. The county abounds in delicious wild fruits, and the present development of small fruits and tree fruits is an indication that their acreage will be greatly increased in the future. Conditions in this section also favor successful commercial bee keeping.

In short, the natural advantages of the Upper Peninsula are such as to indicate extensive growth and development for this section.

Educational opportunities offered in this section are varied and highly developed. Most of the communities possess graded schools located within reasonable distance of all homes, or they have the township plan of organization, in which there is a very high type of supervision. The rural school without township supervision is not, in some instances, all that might be desired, but the situation is being corrected rapidly. It can be said in this connection that the rural situation in the Upper Peninsula is no worse than it is anywhere else. The standards of the rural school teachers of Michigan are much higher than they are in most states of the country, and so the school opportunities in most quarters are very good indeed.

Among the state educational institutions in the district, the Michigan College of Mines and the Michigan State Normal School are noted for their activities and enterprise. Four-year courses leading to the A. B. degree are offered at the schools.

A large and increasing mileage of good roads constructed and under construction allow great opportunities for development in the Upper Peninsula. Transportation facilities, taken in conjunction with the section's proximity to the big markets, such as Chicago, Detroit, Buffalo, Minneapolis, St. Paul, and Duluth, guarantee adequate market outlets.

The Three Great Industries.

The three great industries of the Upper Peninsula are mining, lumbering, and agriculture. Of these agriculture, because of its great possibilities in the section, is destined to become the most important. Mining and lumbering, however, are of importance in their relation to the development of agriculture, and a brief summary of the scope of these industries is of interest.

MINING.

According to the United States Geological Survey of 1916, the total copper production in Michigan was 273,692,525 pounds, valued at $67,328,361, and the silver production was 716,640 ounces, valued at $471,549, giving a combined value of $67,799,910. This is an output of 45 per cent over the value of the output in 1915 and is considered a record production for the district up to that time. A total of $28,840,348 was paid in dividends by fifteen companies, in comparison with $15,000,000 paid by ten companies in 1915.

Iron production in Michigan in 1916 was 18,812,972 tons, valued at $45,848,330. The appraised value of Michigan iron mines in 1916 was $72,997,360 and the ore in stock $19,193,548, a total combined value of mines and ore in stock of $92,190,908.

Nearly one-third of all the iron ore and approximately one-sixth of all the copper produced in the United States are mined in the Upper Peninsula of Michigan.

LUMBERING.

The timber resources of the district are estimated at 30 billion board feet of standing timber. The annual sawmill cut amounts to about 800,000,000 board feet. There is also cut an amount of pulpwood, railroad ties, fence posts, poles, chemical and firewood which totals about as much material as is represented in the sawmill cut. The natural increase, together with the timber now standing, allows for about a forty year cut at the present rate before the present supply is exhausted. Estimating the standing timber as worth $10.00 per thousand board feet, the annual production would have a combined value of from $12,000,000 to $16,000,000 per year.

AGRICULTURE.

That substantial increases have been made within the last ten years is shown by statistics on the agriculture of the Upper Peninsula. In 1910 there were in this section but 8,994 farms, containing 912,080 acres, of which 37 per cent or 339,602 acres were improved. In 1920 there were 12,317 farms, containing 1,181,000 acres, of which 39.4 per cent or 465,546 acres were improved. In ten years the number of farms increased 37 per cent, the land in farms increased 29 per cent, and unimproved land in farms increased 37 per cent. The land in farms in proportion to the whole area increased only 2.5 per cent during this period.

Fig. 3. Sheep on cut-over pasture. There are thousands of acres of fine pasture land now lying idle in the Upper Peninsula.

The total 1920 value of all farm property, land, buildings, implements and livestock totals $69,226,085, an increase of 134 per cent over that of 1910. In 1910 the value of livestock was $4,106,324; in 1920 the total was $10,346,027, an increase of 150 per cent. The above figures indicate a healthy development and are an index of what can be expected in the future.

TABLE 1—DATA SHOWING A GENERAL SUMMARY OF THE VALUE OF ALL FARM PROPERTY AS INDICATED BY AVERAGE VALUE PER FARM AND AVERAGE VALUE PER ACRE.

	All Farm Property	Lands and Bldgs.	Land Alone per A.	Bldgs. Alone per A.	Implements and Machinery	Livestock	Crop Value
Av. value per farm for U. P........	$5,309	$4,144	$28.32	$16.10	$456	$840	$1,185
Av. value per farm for State......	8,976	7,313	50.40	25.09	623	1,040	....
Av. value per acre for U. P........	$56.50	$44.42	....	....	$4.70	$8.76	$31.35
Av. value per acre for State......	92.65	75.48	....	....	4.63	10.73	....

Fig. 4. One of the beautiful roads for which Cloverland is noted.

There is in the Upper Peninsula, an area of 10,702,240 acres, of which 1,181,000 acres are in farms, approximately 1,500,000 acres in Jack Pine plains, 2,700,000 acres in swamp land, and 1,100,000 in cut-over forest land not in farms, leaving a balance of 4,221,240 acres covered with forests.

Eleven per cent of the total area has been taken up in farms, and only 39.4 per cent of this area is improved. Not over 4.5 per cent of the total land area or 7 per cent of the tillable land is improved, leaving enormous areas of good land to be developed. The average acreage per farm is 95.8 acres; the average improved acreage per farm is 37.8 acres. When classified according to size we find that by far the largest number of farms are included in those ranging from 20 to 160 acres or 88.8 per cent of all the farm lands are included in this group.

The number of mars owned in whole or in part by operators totals 11,213; 5,094 are free from mortgage, and 5,131 of the farms are mortgaged. The number of farms reporting debt is 4,810. The value of the land and buildings amounts to $20,922,070, and the amount of mortgage debt is $6,555,877, paying an average rate of interest of 6.1 per cent. Because the agriculture of the territory is new, this reasonable amount of indebtedness is due to acquirement of land, buildings, machinery and livestock. It is a good indication of the conservative and gradual development of the men interested in agriculture in this section, the ratio of mortgage debt to farm value being only 31 per cent. The necessity of extending credit to the new settler in order that he may become a financial success is fully as important as to furnish capital for the development of industrial organizations. The rapidity with which this section of the State will develop will depend a great deal upon the farsightedness of our bankers and businessmen in the extension of suitable credit for agricultural development.

Fig. 5. Well established farms are found on good soils in areas that have been settled over a period of fifteen or twenty years. Farm of A. Anderson, Chatham, Mich.

The number of rented farms in the Upper Peninsula is probably less than in any other equal area. Of the 12,317 farms, only 1,104 farms, or 9 per cent, are operated by tenants and managers. The farms operated by males total 11,798 and those operated by females 519.

Among the many questions which arise from the investigation of the agricultural possibilities, would be that of the class of farmers who are already in the Upper Peninsula. The number of farms operated by native born whites amounts to 3,393, located principally in Chippewa, Delta and Menominee counties; the farms operated by foreign-born whites amount to 8,888, and those by negro and non-whites 36. The reason for the large number of foreign-born whites on farms is undoubtedly due to the opportunity offered the men to work in the mines or lumber camps after their arrival in this country. Many of them had a natural liking for agriculture from habits acquired in the old country, and after saving a little money decided that a better opportunity was offered them in the development of a farm, which they themselves could own and on which they could rear and feed their families.

CROP PRODUCTION.

The total crop area, according to the report of the 1920 Census, was 345,187 acres, exclusive of 117,730 acres in pasture. This area is divided as follows: 67,628 acres in oats; 18,433 acres in wheat; 9,846 in barley; 4,624 in rye; 605 in buckwheat; 222 in navy beans; 6,718 acres in peas; 250,540 acres of hay; 17,401 acres of potatoes; 962 acres of other vegetables; and 697 acres of sugar beets.

The total value of all crops amounts to $14,598,976, divided as follows: cereals, $2,276,978; other grains and seeds, $291,542; hay and forage, $7,395,655; vegetables, $4,213,254; fruit, $308,860; and all other crops, $91,039.

The above figures are of interest in that they show the principal crops and the adaptability of this section to a certain type of agriculture. The main crops in their order of importance are: hay, potatoes, grain and fruit.

The acreage of corn for grain totals 1,000 acres and for forage purposes 2,858 acres, which shows that this, the most important crop in the country farther south, has not become widely used or adapted to this section of the State.

Hay constitutes the largest single item, timothy and clover mixed constituting by far the largest area, or 206,561 acres. Timothy alone takes 20,747; and clover alone 2,731 acres. The alfalfa acreage amounts to 327 acres.

Sugar beets are reported from Menominee and Delta counties. The Upper Peninsula has other areas suited to sugar beet production, and these combined with the favorable climatic conditions, will allow the development of this crop in a suitable rotation.

The average crop yield per acre as estimated by the U. S. Department of Agriculture and Bureau of Markets, Crop Estimates, gives the following averages for a twelve-year period, 1910 to 1921, inclusive:

TABLE 2.—AVERAGE CROP YIELD PER ACRE, UPPER PENINSULA.

Year	Winter Wheat, bushels	Spring Wheat, bushels	Oats, bushels	Barley, bushels	Rye, bushels	Potatoes, bushels	Hay, tons	Buckwheat, bushels
1910	16.0	....	26.0	23.0	20.0	153	1.08	20.0
1911	17.0	....	34.0	27.0	19.0	128	1.64	20.0
1912	22.7	....	32.6	29.5	21.4	140	1.49	20.7
1913	24.9	....	42.8	33.8	22.3	166	1.35	26.2
1914	21.0	....	33.9	33.0	22.2	152	1.30	20.0
1915	27.5	19.1	47.1	38.8	23.8	74	1.80	14.5
1916	18.2	15.0	28.7	26.8	22.4	98	1.77	12.8
1917	20.0	18.0	37.0	29.0	15.7	142	1.50	17.0
1918	18.1	25.1	42.9	32.0	17.0	148	0.94	23.7
1919	14.0	11.7	26.9	19.3	15.7	97	1.40	15.4
1920	13.1	13.1	39.8	24.8	16.8	158	1.35	....
1921	11.7	11.7	18.1	19.3	15.6	104	0.96	....
Average	18.6	16.2	34.2	28.0	19.3	130	1.38	19.0
Michigan 10 year average	17.0	....	34.0	26.0	14.7	91	1.30	14.3
Wisconsin 10 year average	20.7	19.1	37.0	29.4	17.2	103	1.52	15.0
Minnesota 10 year average	17.9	14.8	34.0	24.6	18.8	103	1.54	16.7

HORTICULTURAL PRODUCTION.

The fruit industry in the Upper Peninsula is in its infancy. It has received some set-back due (1) to the planting of varieties not adapted to the climatic conditions of this section and (2) to the planting of unknown varieties which have in recent years come in to bearing and in a great many instances the fruit of which has not been of a good quality. This has had a tendency to discourage the farmers from expanding along the lines they should in order to take care of their home needs.

Fruit-growing depends principally upon climatic and soil conditions. The favorable areas are those situated adjacent to the Great Lakes. They have good air, drainage, and the large bodies of water temper the climate and make conditions favorable for fruit production. The total number of orchard trees not bearing is 100,885, while the number of bearing trees is 176,802. Of the foregoing trees 260,474 are apple, 11,082 cherry, 5,460 plum, and 477 pear. One hundred and twenty-five acres produce strawberries and 14 acres are devoted to raspberry culture. If the fruit trees were uniformly distributed, it would mean that there would be 22.5 fruit trees per farm.

The maple sugar and maple syrup industries have not developed as would be expected of an area having such large numbers of sugar maples. The total number of maple trees tapped amounts to 25,199; amount of maple sugar made, 674 pounds; gallons of maple syrup made, 5,084.

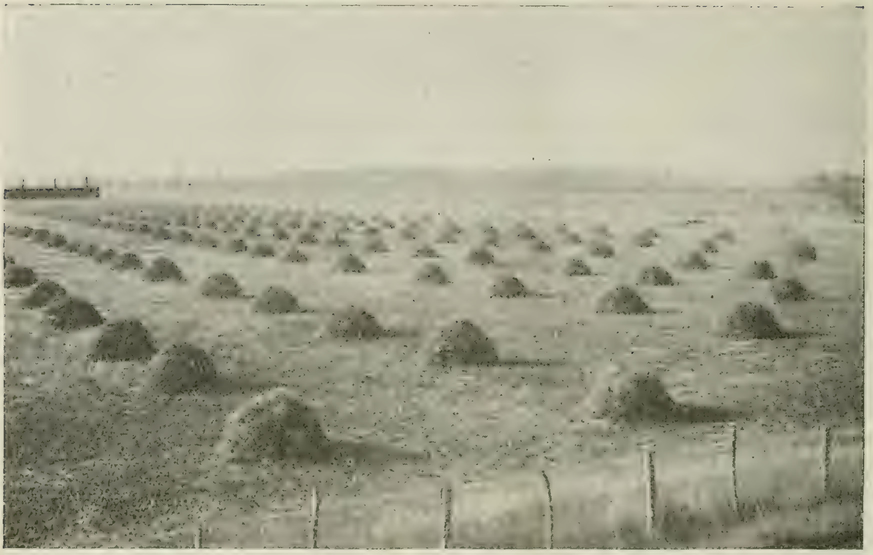


Fig. 6. A field of clover hay located near Escanaba. Clover is the most important legume hay crop in the peninsula.

LIVESTOCK.

The 1920 census shows that the value of domestic animals, poultry, and bees in the Upper Peninsula amounted to $10,346,027, divided according to the following table:

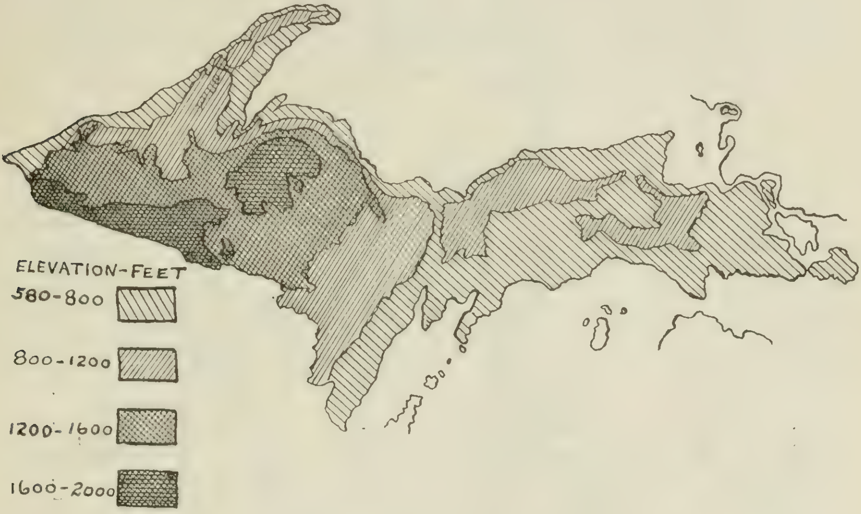
TABLE 3—SHOWING THE 1920 VALUE OF DOMESTIC ANIMALS, POULTRY AND BEES

		Total value	Average per farm
Total number cattle	96,313	$5,307,996	7.8
Total number dairy cows	88,970	4,986,459	7.2
Total number horses	25,069	3,915,404	2.0
Total number swine	22,502	448,551	1.8
Total number sheep	30,401	370,046	2.5
Total number beef cattle	7,346	321,437	.6
Total number poultry	286,688	287,241	23.5
Colonies of bees	496	4,340	....

THE CLIMATE OF THE UPPER PENINSULA[*]

GENERAL STATEMENT.

Considerable differences in elevation and the fact that the territory is nearly surrounded by great bodies of water, give the Upper Peninsula a variable climate. On the elevated sections in the interior, which are some distance from the influence of the lakes, the temperature is extremely low in the winter and the summers are cool. Along the lakeshore, however, the temperature is moderate even in mid-winter. In the latter section, spring frosts are uncommon after May 15 and fall frosts do not usually occur until after October first. The growing season, therefore, in these favored sections is as long as that in central-southern Michigan.



Elevation map of the Upper Peninsula.

In practically all parts of the Upper Peninsula the rainfall is sufficient for growing crops. In fact the rain which comes during the growing season is somewhat heavier than in the Lower Peninsula. One marked characteristic of a narrow strip along the shore of Lake Superior is the heavy snowfall in that section. No place in the United States has more snow than this region.

Tornadoes are practically unknown to the Upper Peninsula, although thunderstorms sometimes develop great energy. The amount of damage on the whole is not extensive. Summer seasons are agreeable and sought by tourists in search of health and pleasure.

The accompanying charts show graphically the outstanding features

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[*] By D. A. Seeley, U. S. Department of Agriculture, Weather Bureau, Lansing, Michigan.

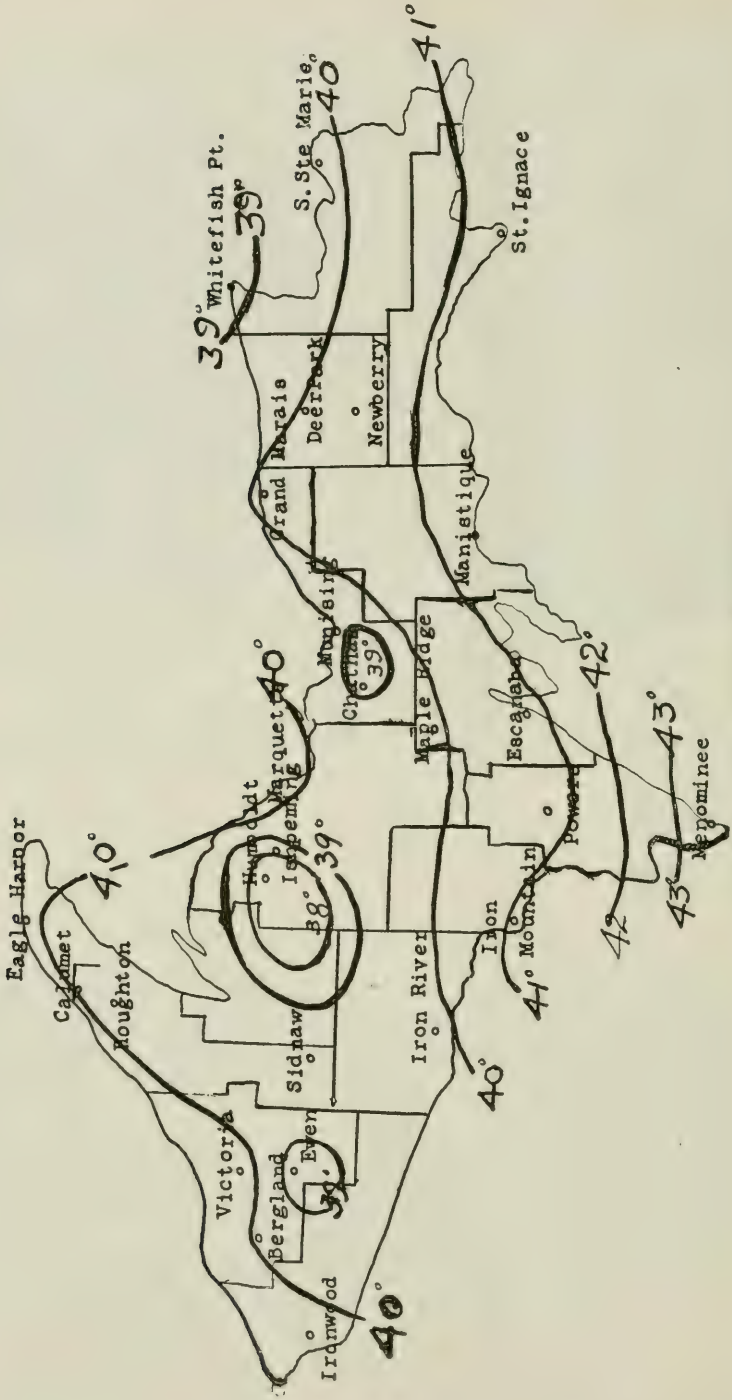

Chart I. Average Annual Temperature.

of the temperature, rainfall, snowfall and frost conditions in the Upper Peninsula.

TEMPERATURE.

The average temperature for the year, Chart I, shows that the coldest section is the central-western portion of the peninsula where the elevation is one thousand to one thousand five hundred feet above the lake level. The highest average temperature is found in the extreme southern portions of Menominee county. The Keweenaw Peninsula, although extending far to the northward, has a mean annual temperature of forty degrees, which is higher than the interior, northern counties of the Lower Peninsula.

Chart II shows the average minimum temperature during the growing season. The coolest weather, on the whole, is in the extreme northern portions of Luce and Chippewa counties. The warmest section is the extreme southern portion of the peninsula, in Menominee county.

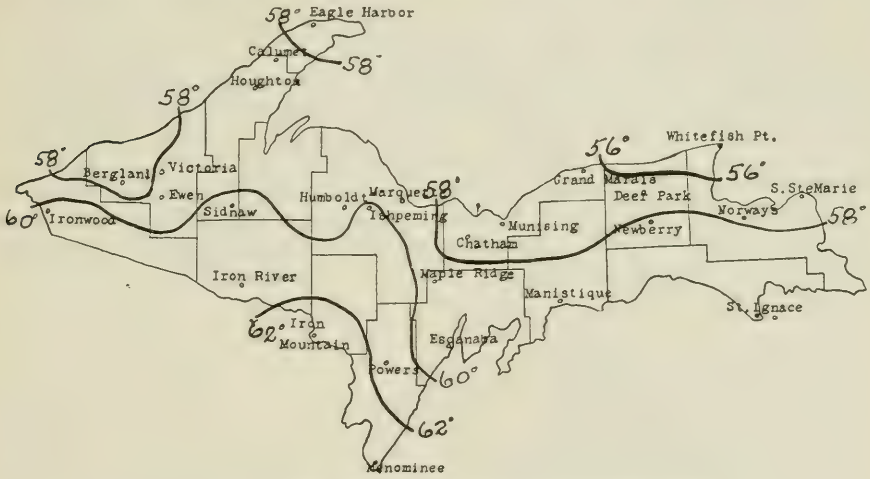

Chart II. Average temperature during the growing season.

The average daily maximum temperature for the growing season is shown in Chart III. The effect of the lakes in keeping down the temperature is marked. It will be noted that the warmest sections, including the elevated regions, are those in the southwestern portions of the peninsula. There is a difference of ten degrees and more between the average high point reached daily by the thermometer in Iron county and northern Chippewa county during the growing season. Between the extreme northern and extreme southern ends of Luce county there is a difference of seven degrees in the average daily maximum temperature. The chart brings out the fact that over most of the counties the temperature is not high enough to grow all farm crops.

This fact is clearly shown in Chart IV, which gives the average daily minimum temperature during the growing season. It shows the temperature is lowest over most of the sections which are highest on Chart III.

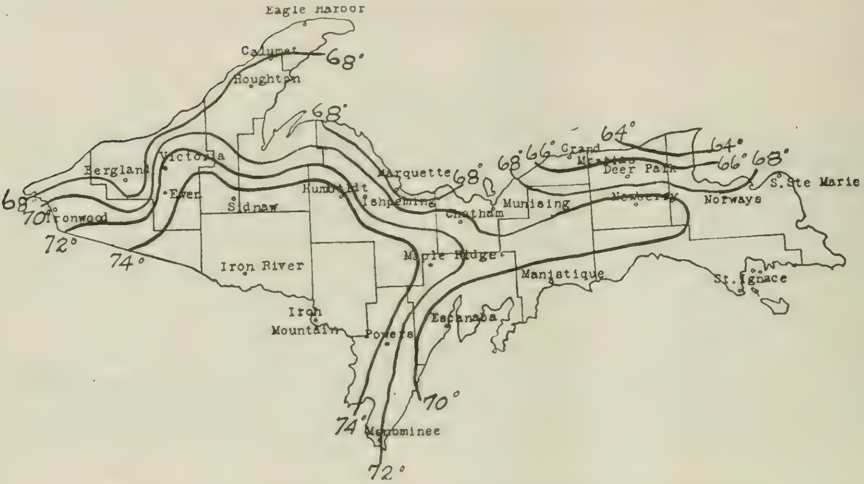

Chart III. Average maximum temperature during the growing season.

At night the temperature falls decidedly over the interior sections, especially where the elevation is greater. The days are warm but the nights are cold. There is, on the average, a difference of twenty-eight degrees between the early morning and afternoon temperatures in interior regions, from Alger county westward. Along the lake shores the range is less than eighteen degrees, on the average. The great body of water, having a fairly uniform temperature tends to hold the adjoining land areas to somewhat the same conditions, not only from day to night but from summer to winter.

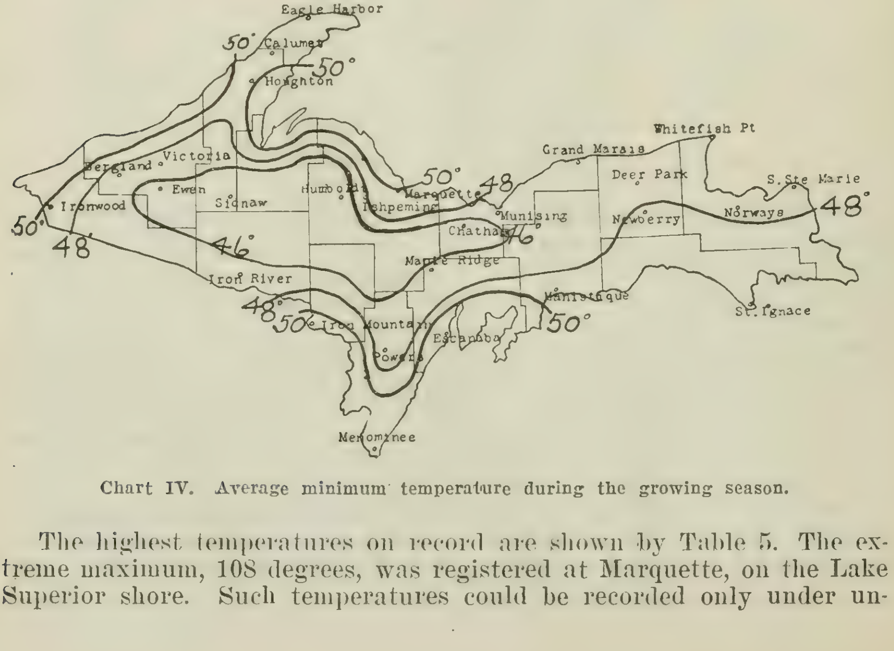

Chart IV. Average minimum temperature during the growing season.

The highest temperatures on record are shown by Table 5. The extreme maximum, 108 degrees, was registered at Marquette, on the Lake Superior shore. Such temperatures could be recorded only under unusual conditions, and maximum temperatures above 90 degrees are rare along the lake shore. It requires a combination of conditions, such as southwestern breezes of just the proper force, a clear atmosphere containing but little moisture and a distribution of atmosphere pressure tending to prevent the shift of wind to "on shore" rather than "off shore" breezes. Usually when the land areas adjoining large bodies of water becomes excessively hot, convectional currents are established with strong breezes from the lake during the afternoon, causing very decided falls in temperature. These are called "land and sea breezes" and are common throughout the Great Lakes region.

It will be noted that temperatures have reached 100 degrees or higher at a majority of places in the Upper Peninsula. This can be accounted for from the fact that southwesterly currents which are usually present during hot waves, have a clear sweep over much of the region, without having crossed large bodies of water. When these currents do encounter large bodies of water they are reduced in temperature as illustrated at Manistique, on the north shore of Lake Michigan where the extreme maximum is but 89 degrees. Another reason for the extremes in temperature in the Upper Peninsula is the clearness of the air in that region, and the fact that the daylight period is longer. The time between sunrise and sunset is 30 to 40 minutes longer in the Upper Peninsula of Michigan than in southern Michigan, during the summer season. (See Table 4.)

TABLE 4—A TABLE SHOWING THE POSSIBLE NUMBER OF HOURS OF SUNSHINE DURING THE GROWING SEASON AT SAULT STE. MARIE AND LANSING, MICHIGAN

Station	Possible hours of sunshine					
	Latitude	May	June	July	Aug.	Total
Sault Ste. Marie	46°-30′	461.8	468.6	474.3	440.4	1,845.1
Lansing	42°-44′	454.7	459.4	464.9	430.7	1,809.7

Table 5 shows the lowest temperature ever recorded at various places in the Upper Peninsula. The extreme lowest, —49 degrees, was registered in the elevated regions of Marquette county, at Humboldt, about 35 miles from Lake Superior. At the city of Marquette, on the lake shore, the lowest ever recorded was −27 degrees. In the Keweenaw Peninsula, although much further north, −24 degrees is the lowest ever reached either at Eagle Harbor or Calumet, clearly showing the temperating effect of the lake. Cold waves come from the Canadian Northwest and are ushered in by strong northwest winds. These must traverse the relatively warm waters of the Great Lakes before striking the land, and their frigidity is markedly reduced. Likewise in the fall season, when great masses of cold air, originating in Northwestern Canada, tend to swoop down over Michigan, the lake water, warmed through the previous summer, gives up its heat to the oncoming cold breezes and frosts are prevented along the immediate lake shore. Further inland these breezes loose their heat again and frosts occur very early in the season. This is strikingly shown in Chart VI.

TABLE 5—DATA SHOWING THE ELEVATION, LENGTH OF RECORD, TEMPERATURE AND PRECIPITATION AT WEATHER BUREAU STATIONS, UPPER PENINSULA.

Station	County	Elevation (feet)	Length of record	Temperature						Precipitation		
				Mean† for the year	Mean† for growing season*	Mean† maximum during growing season*	Mean† minimum during growing season*	Lowest on record	Highest on record	Average for the year	Average during growing season*	Average annual snowfall
Bergland	Ontonagon	1,300	12	39.7	57.0	67.4	46.6	−48	101	31.4	13.9	104
Calumet	Houghton	1,246	34	39.6	58.9	68.0	49.8	−24	101	32.6	12.4	98
Chatham	Alger	875	21	38.9	57.6	70.5	44.7	−44	101	33.3	13.0	107
Deer Park	Luce	610	20	40.0	57.1	67.6	46.6	−38	102	27.3	10.7	87
Eagle Harbor	Keweenaw	622	23	40.1	56.5	66.1	46.9	−24	100	29.0	11.4	......
Escanaba	Delta	612	49	40.9	59.9	68.6	51.2	−32	100	30.4	13.4	58
Ewen	Ontonagon	1,147	21	38.9	59.7	73.9	45.5	−47	101	28.3	10.7	107
Grand Marais	Alger	610	21	40.2	56.9	65.9	47.9	−32	98	29.5	10.5	107
Houghton	Houghton	668	21	39.9	59.8	69.5	50.1	−27	103	32.6	12.8	117
Humboldt	Marquette	1,536	25	37.4	59.2	74.1	44.4	−49	102	25.6	11.0	64
Iron Mountain	Dickinson	1,111	21	41.7	62.8	75.1	50.6	−33	104	27.7	13.7	45
Iron River	Iron	1,504	25	39.2	60.6	74.6	46.7	−47	100	34.1	14.6	65
Ironwood	Gogebic	1,520	19	40.4	60.8	71.6	49.9	−37	96	32.4	13.8	97
Ishpeming	Marquette	1,526	22	39.1	60.1	71.4	48.8	−32	100	32.0	13.4	87
Manistique	Schoolcraft	613	8	41.5	58.4	67.1	49.6	−28	89	32.6	14.3	......
Maple Ridge	Delta	966	15	39.9	59.6	72.1	47.0	−33	100	31.8	13.5	79
Marquette	Marquette	734	51	40.5	59.2	67.9	50.4	−27	108	32.6	12.8	121
Menominee	Menominee	581	23	43.6	63.0	72.3	53.8	−27	102	27.0	12.6	42
Munising	Alger	631	25	39.5	57.7	69.1	46.3	−28	101	30.7	11.5	95
Newberry	Luce	773	20	40.1	59.8	71.4	48.2	−32	97	25.8	10.0	81
Norway	Dickinson	816	3	......	......	......	......	−38	101	......	......	......
Powers	Menominee	868	22	40.7	60.5	74.0	47.0	−39	101	......	......	......
St. Ignace	Mackinac	593	31	41.2	60.8	72.1	49.5	−35	96	27.0	10.7	60
Sault Ste. Marie	Chippewa	614	32	39.6	57.8	68.3	47.4	−37	94	30.0	11.9	70
Sidnaw	Houghton	1,380	12	39.4	......	......	......	−43	98	28.6	11.9	......
Victoria	Ontonagon	1,263	12	40.1	59.4	72.7	46.2	−37	100	31.6	14.1	......
Whitefish Point	Chippewa	610	22	38.9	54.2	62.2	46.3	−30	97	33.4	11.5	104

†Average.
*May, June, July and August.

FROSTS.

Charts V, VI, and VII show, respectively, the average dates of the last killing frost in the spring, the first in autumn and the length of the growing season in various sections of the Upper Peninsula. These are probably the principal limiting factors, as far as the climate is concerned, in crop production in northern Michigan.

The lakes, however, prevent late frost in spring and early frost in autumn, along a narrow strip of shore line and thereby increase the length of the growing season in this limited area by 50 to 60 days, as shown in Chart IX. The time of late spring and early autumn frosts along the lake shores compares favorably with sections in central-southern Michigan and the length of the growing season in the two sections is about equal. In some of the more remote interior districts of the Upper Peninsula, however, frosts occur in nearly every month of the year.

In practically all portions of the eastern half of this region the growing season averages more than 100 days while it is but 80 to 100 days in length, on the average, in all interior, western counties. The length of the growing season decreases rapidly from 147 days at Marquette, on the lake shore, to 79 days at Humboldt, about 35 miles away and 800 feet higher in elevation.

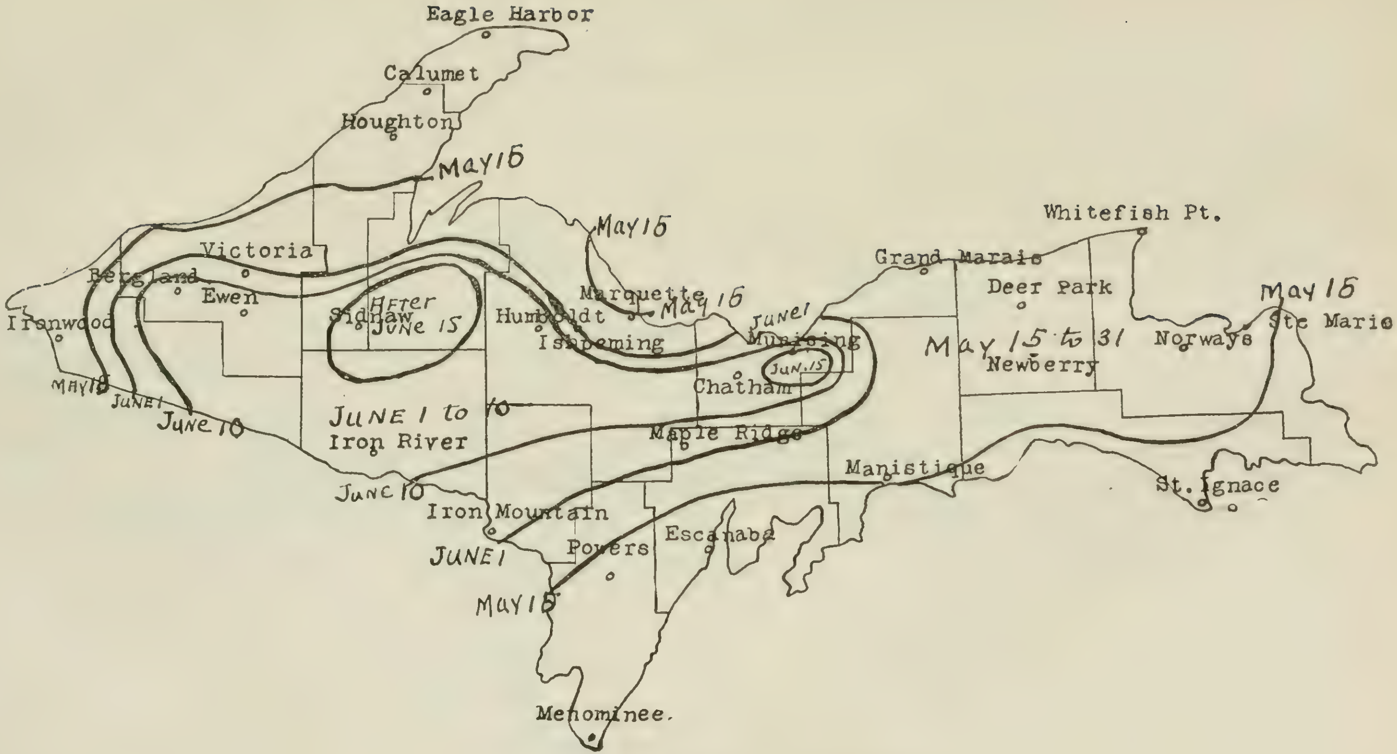

Chart V. Average date of the last killing frost in spring.

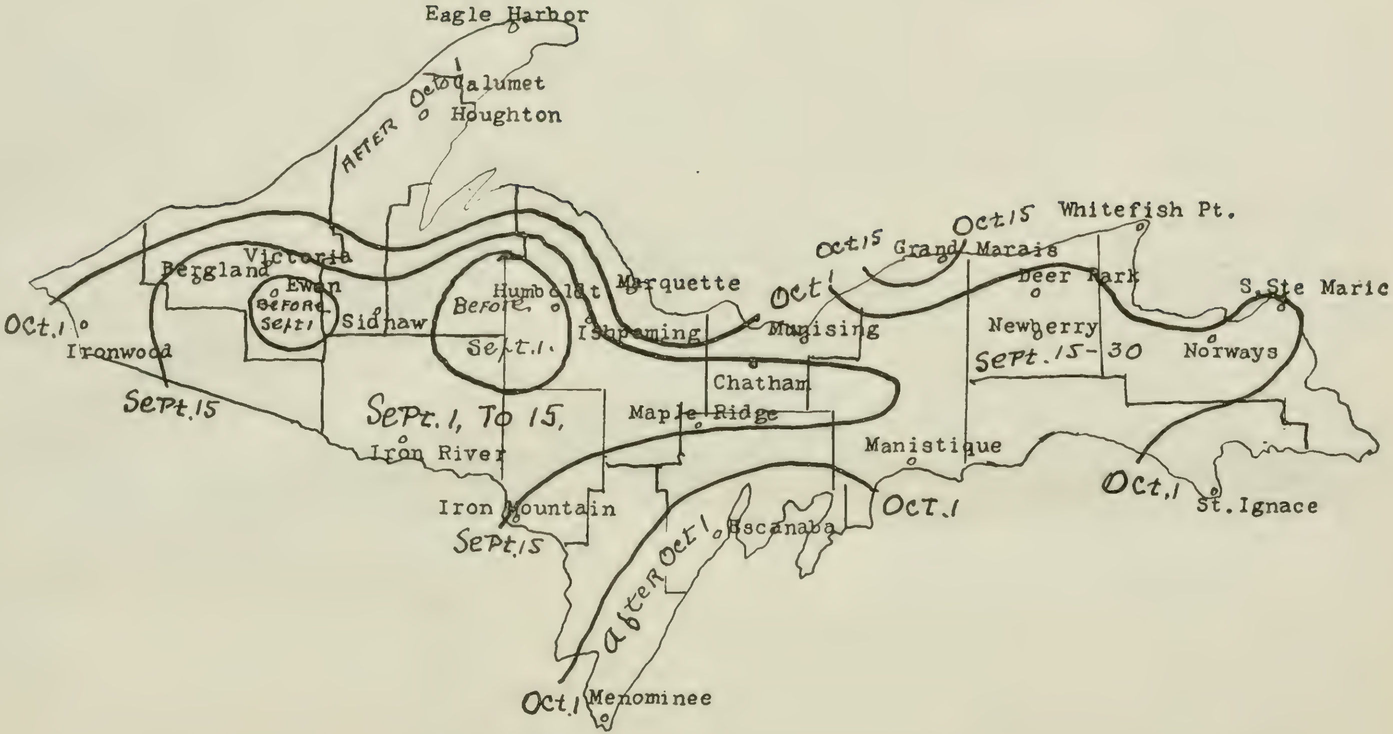

Chart VI. Average date of the first killing frost in autumn.

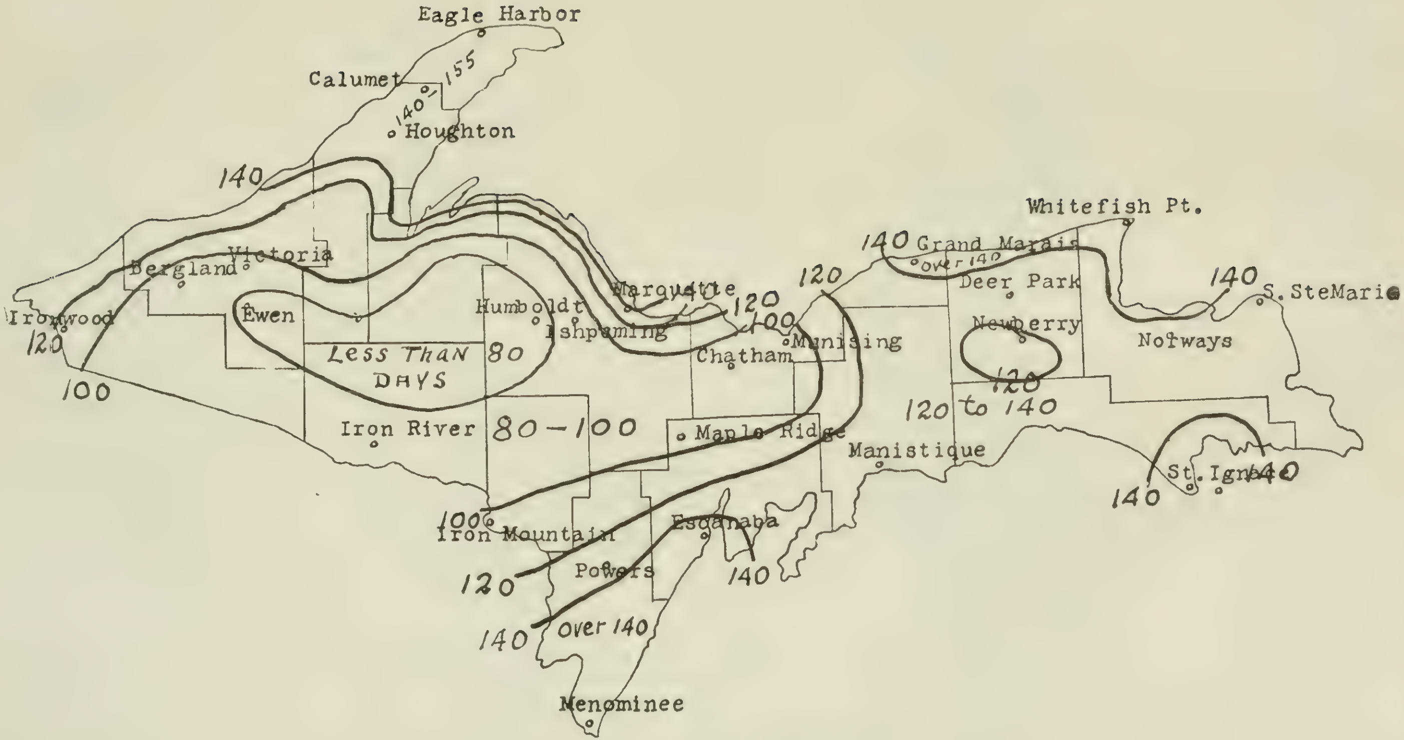

Chart VIII. Average length of the growing season in days.

RAINFALL.

Charts VIII and IX show respectively the normal annual rainfall and the average during the growing season. This rainfall is sufficient for farming operations in general. It is lightest in the interior elevated regions.

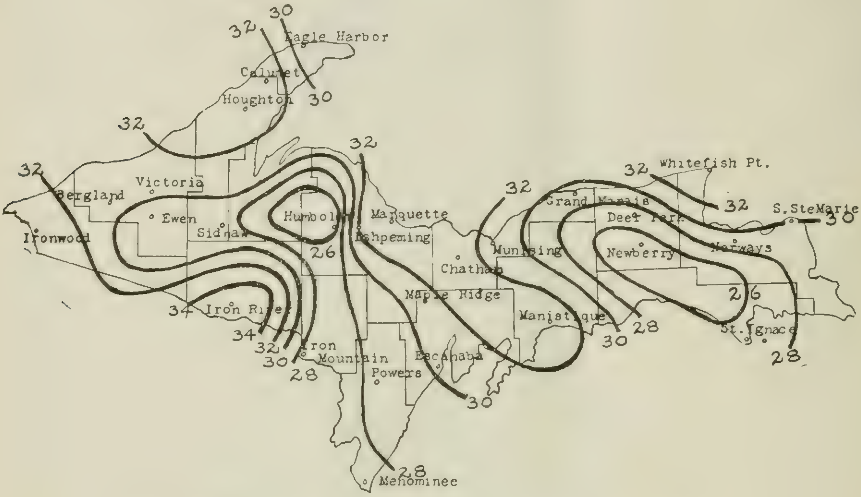

Chart VIII. Average annual rainfall (including melted snow).

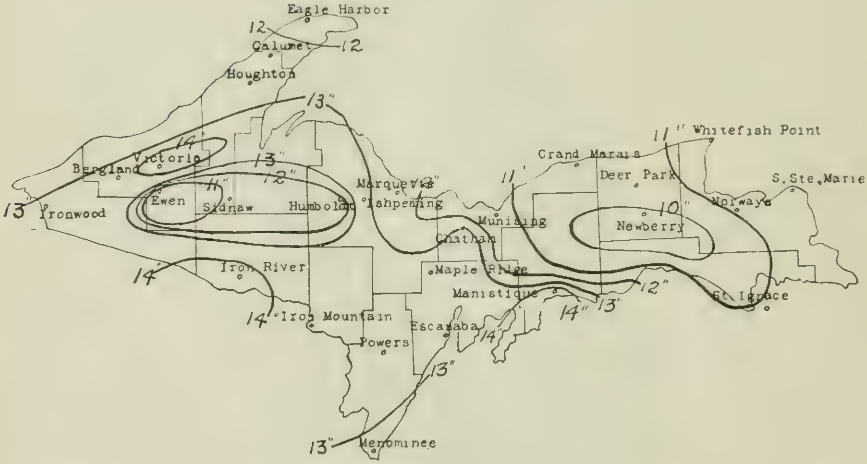

Chart IX. Average rainfall during growing season (May, June, July and August).

Chart X shows the average annual depth of snowfall. Here again the effect of Lake Superior is clearly brought out. The heaviest snow occurs along its shores where the moisture-ladened air comes in contact with the cold land areas and the moisture is condensed into snowflakes. Snow piles up to great depths along the shore, and several miles inland, decreasing gradually away from the lake.

TABLE 6—DATES OF FROST AND THE AVERAGE LENGTH OF THE GROWING SEASON, UPPER PENINSULA, FOR TEN YEARS OR MORE.

Station	County	Average date of the last killing frost in spring	Average date of the first killing frost in autumn	Average length of the growing season, in days	Latest date killing frost recorded in spring	Earliest date killing frost recorded in autumn
Bergland	Ontonagon	June 9	Sept. 6	89	Jun 28	July 25
Calumet	Houghton	May 13	Oct. 5	153	May 30	Sept. 16
Chatham	Alger	June 14	Sept. 3	81	June 30	July 16
Deer Park	Luce	May 27	Sept. 27	123	June 28	Aug. 9
Eagle Harbor	Keweenaw	May 24	Oct. 14	143	June 7	Sept. 13
Escanaba	Delta	May 11	Oct. 5	147	June 5	Sept. 14
Ewen	Ontonagon	June 12	Aug. 29	78	June 23	July 19
Grand Marais	Alger	May 17	Oct. 15	151	June 1	Sept. 12
Houghton	Houghton	May 11	Oct. 9	151	May 26	Sept. 27
Humboldt	Marquette	June 8	Aug. 26	79	July 1	July 16
Iron Mountain	Dickinson	May 27	Sept. 26	123	June 15	Sept. 5
Iron River	Iron	June 2	Sept. 9	89	June 30	July 21
Ironwood	Gogebic	May 22	Sept. 23	124	June 23	Aug. 25
Ishpeming	Marquette	June 8	Sept. 16	101	June 22	Aug. 4
Manistique	Schoolcraft	May 16	Sept. 20	127	May 27	Sept. 5
Maple Ridge	Delta	June 10	Sept. 14	97	June 27	Aug. 30
Marquette	Marquette	May 13	Oct. 6	147	June 5	Sept. 28
Menominee	Menominee	May 12	Oct. 8	149	June 21	Sept. 16
Munising	Alger	June 19	Sept. 19	92	June 28	Aug. 27
Newberry	Luce	May 26	Sept. 23	120	June 23	Aug. 27
Powers	Menominee	May 31	Sept. 11	104	June 27	July 19
St. Ignace	Mackinac	May 13	Oct. 4	145	June 28	Sept. 1
Sault Ste. Marie	Chippewa	May 15	Sept. 30	138	May 29	Sept. 5
Sidnaw	Houghton	June 17	Sept. 5	80	June 28	Aug. 17
Whitefish	Chippewa	May 22	Sept. 13	144	June 30	Sept. 21

TABLE 7—DATA FROM REPORTS COVERING TEN OR MORE YEARS WHICH SHOW THE AVERAGE TEMPERATURE AND RAINFALL PER MONTH AT THE WEATHER BUREAU STATIONS OF THE UPPER PENINSULA.

MEAN AVERAGE TEMPERATURES.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual mean
Bergland	9.7	12.2	24.8	39.6	51.3	61.7	66.1	62.6	55.1	44.4	31.1	18.2	39.7
Calumet	15.2	13.3	23.1	37.4	48.5	59.6	64.5	62.3	55.5	44.2	30.7	20.6	39.6
Chatham	13.8	12.9	23.3	36.1	47.5	58.1	63.4	60.8	54.2	44.3	32.6	19.6	38.9
Deer Park	17.9	14.9	24.0	36.2	46.9	56.5	62.8	62.2	56.2	45.8	34.0	22.3	40.0
Eagle Harbor	17.8	15.2	25.5	37.2	46.2	55.2	62.1	61.7	56.0	45.3	35.1	23.8	40.1
Escanaba	15.3	15.2	24.1	37.4	49.3	60.7	66.4	64.3	57.0	45.9	32.9	21.8	40.9
Ewen	11.2	11.8	23.5	36.1	50.6	60.6	65.2	61.3	54.9	44.6	30.3	16.5	38.9
Houghton	13.9	13.9	22.4	36.8	49.2	59.5	65.7	63.6	56.5	44.0	31.6	21.5	39.9
Humboldt,	10.3	9.6	20.2	34.8	49.0	59.1	63.3	60.2	53.8	43.0	28.5	16.4	37.4
Iron River	11.0	11.2	24.2	39.2	51.2	60.2	65.4	62.5	55.2	44.1	29.7	16.5	39.2
Marquette	15.9	15.9	23.7	37.5	49.0	58.5	64.9	63.5	56.8	45.7	31.9	22.9	40.5
Menominee	17.3	16.7	28.7	40.2	51.4	64.4	69.0	66.7	59.9	49.5	35.9	23.3	43.6
Newberry	15.1	13.3	23.9	39.0	50.2	59.4	65.2	62.3	54.8	45.7	32.0	20.6	40.1
St. Ignace	18.7	14.7	24.3	38.9	51.0	59.8	65.4	63.7	57.9	40.7	34.3	24.9	41.2
Sault Ste. Marie	13.3	13.4	21.3	35.7	47.7	57.6	61.9	60.6	54.3	43.4	30.7	20.5	38.4
Whitefish Point	17.0	13.4	22.8	34.4	44.1	53.1	59.6	60.9	56.0	46.6	34.6	23.8	38.9

PRECIPITATION (RAINFALL)

Bergland	1.59	1.38	1.84	1.90	3.16	3.30	3.94	3.49	3.30	3.20	2.02	2.27	31.39
Chatham	1.96	1.77	1.51	2.05	2.80	3.55	3.49	3.16	4.21	3.23	3.06	2.50	33.29
Eagle Harbor	1.55	1.61	1.94	2.23	2.91	2.92	2.62	2.99	3.23	2.36	2.37	2.22	28.95
Escanaba	1.47	1.43	1.94	2.15	3.14	3.44	3.35	3.47	3.38	2.93	2.19	1.68	30.42
Ewen	1.79	1.68	2.14	2.07	2.54	2.78	2.94	2.46	3.01	2.03	2.53	2.32	28.29
Houghton	2.04	1.71	2.10	2.03	3.29	3.49	3.10	2.87	3.54	3.18	2.80	2.47	32.62
Humboldt	1.24	0.95	1.48	1.77	2.31	3.06	3.19	2.47	3.40	2.38	2.12	1.28	25.65
Iron River	1.44	1.46	2.40	3.24	3.60	4.31	4.52	2.01	3.92	3.20	2.22	1.76	34.08
Marquette	2.04	1.72	2.08	1.99	3.32	3.51	3.10	2.86	3.51	3.19	2.79	2.52	32.63
Menominee	1.06	1.12	1.57	2.32	3.08	3.06	3.66	2.84	3.09	2.31	1.72	1.17	27.00
Newberry	1.69	1.26	1.76	1.66	2.61	2.89	2.05	2.44	2.94	2.67	2.26	1.56	25.79
St. Ignace	1.82	1.29	1.56	2.03	2.81	2.36	2.94	2.59	2.55	2.54	2.66	1.88	27.03
Whitefish Point	2.26	1.75	2.20	2.17	3.07	2.84	2.90	2.65	3.99	3.08	3.27	3.17	33.35

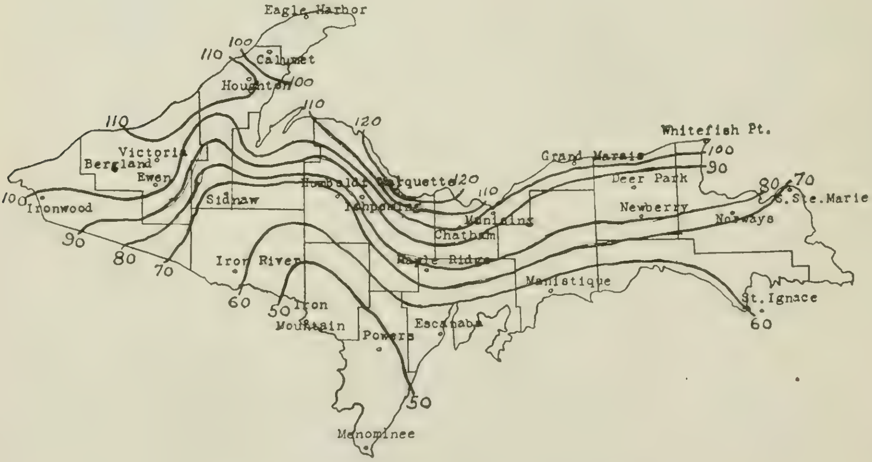

Chart X. Average annual snowfall in inches.

THE SOILS OF THE UPPER PENINSULA.*

A considerable variety of soils is found in the Upper Peninsula. These soils range from heavy clays to sandy soils, including a number of types of loams between these extremes. It has been estimated that 65 per cent of the soils of the district may be used in productive agriculture.

Two general classes of swamp lands are also found. The first of these comprise small upland swamps, in some cases occupying what were originally small lakes or ponds and formed of materials which have largely grown in or upon these waters until the accumulations now occupy the place originally occupied by them. The second of these which may be termed lowland swamps, occupy much larger areas, but have been formed in much the same manner.

Fig. 7. Substantial farm buildings are an indication of a good farm and prosperity. Barns on the Fleming farm near Matchwood, Ontonagon County.

DISTRIBUTION OF SOILS.

In general, soils often vary within short distances, so that on a single forty acres may be found sands, clays, loams and muck. On the other hand, there is a rather marked geographic grouping of types of soil.

Clays—The Superior clay may be said to be found in three groups. The first occupies eastern and southeastern Chippewa county, extending somewhat into northern Mackinac county. In this area is found the oldest agriculture in the State of Michigan. The second clay area occupies a considerable portion of the Ontonagon Valley. The third clay area comprises probably 100,000 acres in the Sturgeon River valley. A fourth and smaller area of clay lies adjacent to Huron Bay and Keweenaw Bay.

The clays vary in depth from a few inches to 200 or more feet. At Ewen, the clay reaches a depth of over 200 feet.

Loams and Sands—Adjacent to but lying chiefly to the west and south of the clays are extended areas of loams, tapering or merging in many instances into sandy soils and sands.

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*By Jos. A. Jeffery, Agr'l Development Agent, D. S. S. & A. Ry. Co. in co-operation with the Experiment Station.

There are extended areas of loam soils. One of the most characteristic of these includes the greater part of Menominee county, western and northwestern Delta county, southern and eastern Marquette county and western Alger county.

The loams adjacent to the clay areas are frequently underlaid by clay.

Bordering Lake Michigan and Lake Huron and at points reaching well northward toward Lake Superior are deposits of limestone and calciferous shales. Loam soils, of which there is a considerable area, immediately over-lying these deposits, possess splendid agricultural values.

Swamp or Muck Soils—The chief areas of these lands lie in the eastern part of the peninsula and occupy considerable portions of the valleys of the Taquamenon, Manistique and Carp Rivers. Those of the Taquamenon and Manistique valleys practically merge, so slight, for some miles, is the water shed separating the valleys. The depth of the swamp soils range from a few inches to many feet. They are underlaid in some cases by sands, and in some cases by clays or loams.

CROP ADAPTABILITY.

Clays—The clay soils are especially suited to the growing of grasses and clovers, especially alsike clover. Indeed, so natural is alsike clover to these soils that thousands of acres have become self-seeded to it. The original seed undoubtedly came from hay hauled to logging camps. As a rule, hay, grain and pasture crops are the principal ones grown on these lands. Of the grains, wheat, oats, barley and rye produce good yields. Peas do especially well, and excellent yields of clover seed are obtained. The Superior clay is not suited to commercial growing of potatoes. Turnips and beets are usually grown for livestock and produce good yields. Small fruits, especially the bush fruits, and the early varieties of apples are successfully grown.

Loams—The loams are especially suited to the grasses, clovers (usually June or Mammoth), grains, potatoes and roots. Sugar beets have been grown successfully in many places. It is upon these soils that the Upper Peninsula is acquiring its reputation for yields and quality of potatoes. It should be borne in mind, however, that soils closely underlaid by limestone and formed in part from them, such as the soils of the Upper Peninsula Experiment Station, are generally abundantly affected by potato scab disease. With such a condition, in seasons favorable to the development of scab, the marketability of the crop may be greatly reduced.

Small fruits, cherries, plums and the early varieties of apples do well.

***Muck**—The muck soils of the Upper Peninsula will vary slightly, if at all, from those of Southern Michigan in cropping values. When properly managed it is safe to assume, they will excel in the production of timothy, blue grass, and alsike clover, and will produce good yields of the crops known to be suited to muck soils. They will give fair to excellent yields of rye, oats, barley, sunflowers, etc. The limiting factor at this time, in the case of grains, is the possibility of late and early frosts.

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*In the tillage of muck soils, probably the most difficult, and at the same time the most important thing to accomplish, is the proper compacting of the upper twelve to eighteen inches of soil. The purpose is to establish proper capillary moisture relations in the surface soil. For this purpose, a very heavy roller is required, one that, with a 30 inch diameter weighs somewhere from 350 pounds to 800 pounds to the linear foot. A roller commonly recommended is one made by centering a shaft within 3 feet or 4 feet lengths of 30 inch culvert tubing and then filling with concrete. When these lengths are properly set in a roller frame, the weight will amount to about 750 pounds per linear foot. The advice of expects is to roll grain at least at time of planting, and to roll hay meadows in spring, and after cutting, and to roll pasture meadows "frequently."

MANAGEMENT.

Clays—The clays are heavy to work when first brought under cultivation, but greatly improve when care is exercised in the use of tillage tools, proper crop rotation, and the incorporating of organic matter in them. These soils will prove to possess great durability and productiveness.

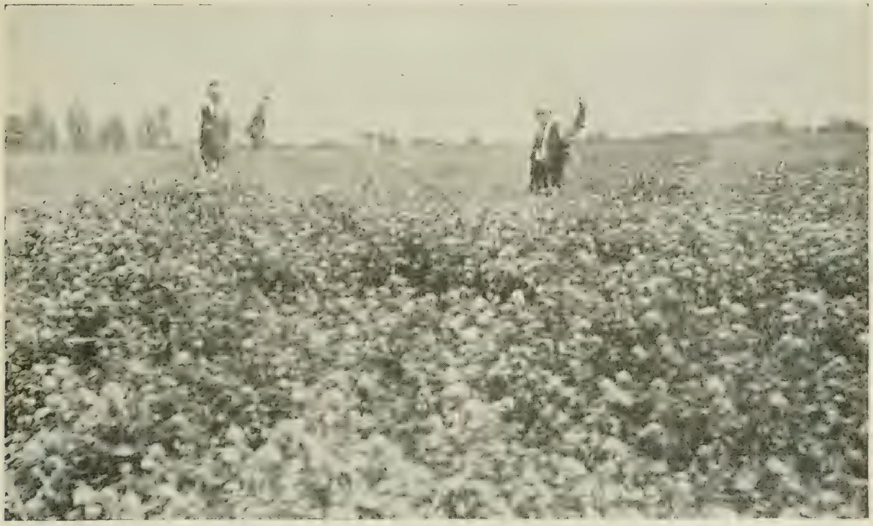

Fig. 8. Clover field of O. F. Branns, Merriman, Dickinson County. This shows one reason why Michigan's Upper Peninsula is called "Cloverland."

Loams—The loams possess a wide range of crop adaptation and because of this fact, are frequently abused by heavy cropping and poor management. A careful plan of crop rotation should be practiced.

Sandy Loams—The sandy loams must be handled intelligently if their productiveness is to be maintained. Short rotations should be practiced and goodly amounts of organic matter must be returned to the soil.

Muck Soils—Experience so far indicates that these soils will require management identical with that of muck soils elsewhere. Drainage must be provided; but extreme care must be exercised, particularly where the muck is underlaid by sand, not to over-drain. Corrective treatments of potash are apparently sure to be required. Barnyard manure will always prove helpful. Lime will be required in some instances.

CAUTION.

It is unwise at any time for one to purchase land (especially new land) without careful, personal examination, or have it examined by some reliable party who is known to be competent to do so. The nature of the soil, its location, its topography and its proximity to markets, to good roads, to a good school and agreeable and compatible social conditions are all matters of prime importance.

Field Crops in the Upper Peninsula.*

There is a wide range of field crops which can be produced profitably in the Upper Peninsula. The great variation in length of growing season makes it necessary, however, to select varieties especially adapted to the section, as each section is influenced by its elevation and proximity to the lakes.

The forage and root crops are especially adapted, while many small grains and legumes can be produced profitably. Marketing facilities and generally favorable conditions make possible the development of this country as a great crop and livestock section.

CLIMATE.

The climate limits the adaptation of crops by the length of growing season, the amount and distribution of moisture, the amount and distribution of sunlight and the general character of the days and nights during the growing season. It has been pointed out in the previous

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*The results herewith given are the conclusions derived from three years of experimental work with crops in accordance with plans projected in 1917 by the Farm Crops Division of the Michigan Agricultural College, developed and elaborated by G. W. Putnam, delegated to the Upper Peninsula as Crops Experimenter.

Fig. 9. The first clearing and buildings of the new settler in the timber and cut-over lands. Root crops, potatoes, peas and clover are well adapted to the conditions of the new settler.

discussion on climate, that the Upper Peninsula is subject to a very great diversity of climate conditions, which tend to limit or extend crop production, depending on the location within the peninsula. In general, the climate of this area is favorable to such crops as require or can tolerate an abundance of rainfall, and rather long days with comparative cool nights, through a comparative short growing season.

CROP ADAPTATION TO SOIL TYPES.

The adaptibility of a given soil to produce crops is limited by its texture, whether it is a heavy clay, clay loam or sandy loam; its content of available plant food elements, such as potash, nitrogen, phosphorus, and the other elements necessary for plant growth; the lime content, whether a soil is acid or alkaline; its organic content, straw, manure and other vegetation incorporated in the soil; its water holding power; its drainage, natural or artificial. The combination of these factors in any given soil determines its type and fertility.

The previous discussion on soils points out the wide variation in soil types to be found in this area. In order to determine the crops best suited to a particular section of the Upper Peninsula, it is necessary to consider the local climatic conditions together with the type of soil to be cropped.

The clays and clay loams are primarily adapted to hay, forage crops and small grains. The loams and sandy loams are adapted to potatoes and root crops, as well as the hay, forage and small grains produced on the heavier soils.

CULTURAL METHODS.

The practice of fall plowing is one in general use throughout the area, and is to be commended. There are several distinct advantages in fall plowing: 1st, the soil is in shape to absorb and hold more moisture for the following crop; 2nd, you can get on to the land early in the spring and prepare the seed bed well in advance of planting, thereby permitting the killing of several crops of weeds and keeping the soil in good condition; 3rd, it allows of the partial decomposition of the organic matter so that it becomes more readily available for plant food when the plants are ready for it later in the season; and, fourth, the effects of freezing and thawing work the soil particles and organic matter into a more uniform mixture. This prevents the formation of a strawy layer at the bottom of the furrow slice which is a distinct disadvantage in the production of a maximum crop.

IMPORTANCE OF GOOD SEED OF HIGH GERMINATION.

The importance of good seed cannot be over emphasized. Today, the best farmers throughout the Upper Peninsula are turning from scrub livestock of unknown production to improved herds. The same farmers are beginning to question the wisdom of sowing scrub seed of unknown production on good soil and are rapidly turning to some dependable variety of known production. It is not so much a question of what variety to grow as it is a question of whether or not it is a dependable one. Then to treat the seed in such a way as to insure a good stand that will be reasonably free from controllable diseases. Such treatment includes the use of the fanning mill to remove (1) light undeveloped kernels which if planted would result in weak plants, (2) to remove dirt and chaff that would influence the rate of seeding and possible clogging of the drill.

The germination test will insure seed of high vitality. This is very important in some seasons when the weather has been such that grain may not have become properly fertilized or may have become damaged in the shock, stock or storage bin. Seed grain should be treated with formaldehyde to control smut. It is estimated that from 10 to 15 per cent of our cereal grain crops is lost each year on farms that do not treat grain for smut. In 1918, a demonstration on Budd Wilbur's farm in Haight twp., Ontonagon county, gave the following results with oats:

Treated area, yield per acre....................	50 bushels
Untreated area, yield per acre	37.5 bushels
Increased yield on treated area	12.5 bushels

In this case, the loss from untreated seed with 25 per cent. The cost for treatment is so slight (3 to 5c per bushel) that it is one of the cheapest insurance policies that can be carried on any farm.

TIME TO SOW SPRING GRAINS.

Early sowing is an essential practice to high production in the Upper Peninsula. It takes from 85 to 100 days from time of planting until harvest to produce a crop of oats, barley, or spring wheat in this section. The first 55 to 65 days is utilized in developing the plant up to the heading stage, the remaining 25 to 40 days is utilized in developing and ripening of the kernels. The exact number of days in the different stages will vary with the variety grown and the character of the season. A glance at the weather report (table 7) from the various sections

Fig. 10. Alfalfa is well adapted to many sections of this country. This picture was taken in September after a crop of barley had been removed in August.

of the Upper Peninsula shows that May and June are ideal growing months and from July 1 to August 15 is usually weather favorable to kernal development and ripening. This would indicate that about May 1 is the time to sow spring grains in this area so as to make the best use of our weather conditions. The practice of our most successful farmers is to sow their spring grains as early in May as possible.

RATE TO SOW PER ACRE.

This is a cultural practice that will vary with the grain crop grown and the type of soil under cultivation. The usual rate for spring wheat is from 5 to 8 pecks per acre. When seeded early on a well-prepared seed bed with a soil suitable for wheat, 6 pecks is about right. Oats should be sown at the rate of 8 to 12 pecks per acre. Ten pecks is about right for the average soil, 8 pecks on the lighter soils and 12 pecks on the real heavy soils. Barley should be sown at about 8 pecks per acre on average soil, about 7 pecks on light soil, up to 9 or 10 on the heavier soils.

Field peas* are so variable as to size that it is difficult to recommend a definite rate for sowing. The smaller sorts, such as the French June and Golden Vine at about 2 bushels per acre. The medium-sized, like English and Arthur, at from 2½ to 3 bushels. The larger sorts, like the Marrowfat, from 3 to 3½ bushels.

TABLE 12—RATE OF SOWING SPRING GRAINS.†

†All tabulated data pertaining to crops in this publication is the result of experimental work done at the U. P. sub-station of the Michigan Agricultural College, at Chatham, Mich., unless otherwise noted.

Wolverine Oats		Wisconsin Pedigree Barley		Chang Field Peas (Small to medium size)	
Rate sown per acre (bu.)	Yield per acre (bu.)	Rate sown per acre (bu.)	Yield per acre (bu.)	Rate sown per acre (bu.)	Yield per acre (bu.)
2	88	1½	33	2	57.5
2½	101	2	38	2½	57.5
3	100	2½	41	3	54.5
3½	103	3	38.5	4	48
4	83	3½	41		
4½	85				
5	85				

The preceding data confirm the rates recommended in the preceding paragraph. In some sections there is a tendency to sow heavier on the lighter soils than on the more fertile ones. This is contrary to our knowledge of light soils, as they tend to be more droughty and less fertile and a somewhat lighter seeding will utilize available moisture and plant food to best advantage. The heavier seeding would tend to produce a greater number of plants, all of which would be of inferior quality.

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*Field peas, as a grain feed crop, occupy a place in our system of cropping in the Upper Peninsula very similar to the small grains, so they are herein treated under the same cultural heading.

BROADCAST SOWING VS. DRILLING.

Wherever possible grain should be seeded with a drill. When field conditions make this impracticable the seed may be broadcasted. Drilling permits of a uniform rate and depth of sowing and with much of our grain sowing, a grass seeding is made.

HARVESTING THE GRAIN CROP.

The humid climate of the Upper Peninsula is a handicap to the production of bright, clean grain. More of our musty, off-colored grain comes from the way it is handled at harvest time, than from any other source.

Spring Wheat—Wheat should be well ripened before cutting, but not over-ripened. The lower parts of the stem and roots die first and the proper time to cut is when only a slight tinge of green is left in the upper part of the stem. If allowed to become over-ripe, wheat tends to shatter and produce a higher percent of "yellow berry."

Oats—The time to cut oats is in the dough stage. Unlike wheat, oats are heavier if cut in the dough stage and will have a brighter color. The handling of the oats from time of cutting until threshed, will very largely determine the quality of the grain.

Barley—The barley should be cut when ripe. If it is cut in the dough stage, shriveled kernels will result. Usually the hull on barley will start to wrinkle when ripe, the water starts drying out of the berry as soon as the process of storing starch in the berry is completed, which causes the wrinkling. That is the time to cut and let the water dry out in the shock.

Field Peas—The usual method of harvesting peas where they are grown on a very large scale, is to use the harvesting attachment for mowing machines, with this attachment consisting of special guards, peas can be handled quite economically. The peas when harvested with machinery, should be ripe to the point that the vines are dry, as they handle much better in this way, and can be handled directly from the field. Peas should not be left in contact with damp ground for any length of time, as they bleach out and their market value is lessened.

VARIETIES TO GROW.*

There is a very great range in the merits of our various crop varieties. Improved, high-producing varieties are usually the result of experimental work conducted by the various state experiment stations, and carried on by Crop Improvement Associations.

The Michigan Crop Improvement Association is organized to carry on the work in this State, and under the direction of this Association, large acreages of our various farm crops are grown each year for seed purposes, thus saving us from having to use seed which has become badly mixed and contaminated with scrub varieties. Through the

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*Pedigreed grain varieties mentioned in this bulletin may be secured from the Michigan Crop Improvement Association, East Lansing, Mich.

Michigan Crop Improvement Association it is possible to buy seed grain in any quantity and of known quality.

One big problem in connection with selecting a variety for any particular section is that of standardization. This is particularly true with certain crops. Marquis spring wheat is practically the standard wheat variety of the Upper Peninsula. Oderbrucker and Wisconsin Pedigree are the standard barley varieties of this area. On the other hand, oat and field pea varieties are not so well standardized. An inquiry in any particular farming community will usually disclose the fact that there are nearly as many varieties of oats and peas as there are growers.

STANDARDIZE ON A FEW VARIETIES.

The time will probably never come when only one variety of the various crops will be the standard of the State. Neither is it necessary, however desirable, to standardize on a comparatively few varieties of each crop in a section like the Upper Peninsula. In so far as possible, however, only one variety of each crop should be grown in one community.

The advantages of standardization are: 1, the danger of mixing varieties by use of the community threshing machine is lessened; 2, if a surplus is produced in the community, there is usually a better market for a standard product in quantity than for smaller lots of many varieties; 3, if a particular variety has special merit for a given community, all the growers in that community will benefit by it; 4, it makes possible a community co-operative crop test to determine the best varieties.

Varieties of Small Grains Recommended for the Upper Peninsula.

SPRING WHEAT.

Experimental work at the Upper Peninsula Experiment Station and notes made by the various agricultural workers throughout the Upper Peninsula, indicate that spring wheat is subject to black stem rust. There is no known control for this disease nor are there any resistant spring wheat varieties of sufficient commercial value to warrant their use under Upper Peninsula conditions. There are local areas especially in the Superior clay districts, where the epidemics of this disease are not as serious and spring wheat may be a profitable crop.

Marquis is the best adapted spring wheat for the areas where it can be grown.

OATS.

Wolverine—This is a pedigreed strain developed by Professor F. A. Spragg, of the Michigan Experiment Station, at East Lansing. Experimental work at Chatham and co-operative tests throughout the Upper Peninsula have demonstrated this variety to be a consistent high producer. It is an open panicle white oat.

Worthy—This is another pedigreed strain developed by Professor F. A. Spragg. It is also an open panicle white oat, especially well adapted to heavy soils because of its stiff straw which lessens its likelihood of lodging.

Swedish Select—This is probably the most widely grown oat variety in the Upper Peninsula. It is a good dependable variety adapted to this section. There is one draw-back to using Swedish Select, it is usually difficult to obtain pure strains. There are a great many fields of oats grown under the name of Swedish Select that obviously are not true to name. When buying Swedish Select oat seed, one is very apt to get a mixture of many varieties or possibly some other variety entirely. The Upper Peninsula Experiment Station has made selections of true Swedish Select, but it will be some time before these selections will be ready for distribution.

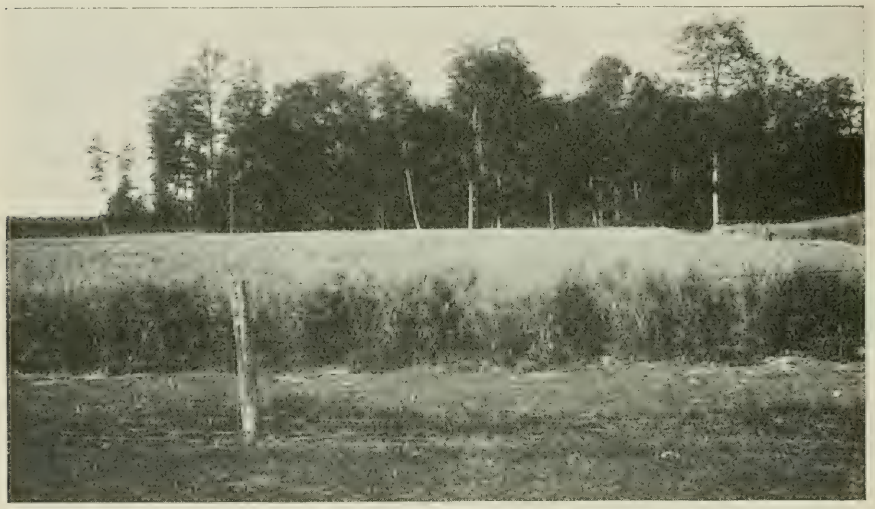

Fig. 11. The soil and climatic conditions of the Upper Peninsula are ideal for maximum yields of oats. The Wolverine is a dependable variety for this section.

Iowa 103—This variety, or one of the other strains of Sixty-day or Kershon Oats, is needed to fill a special purpose. This type of oat is about two weeks earlier than the preceding three varieties. Under seasons of unfavorable growth, because of dry weather, such as the seasons of 1919 and 1921, this type of oat will out-yield the other varieties. In the areas where grasshoppers have been bad the past two years, it has been observed that these early oats usually come on and produce grain before serious injury occurs from the grasshoppers. They should be given a trial in those areas that may reasonably expect another outbreak of these pests. They produce a much smaller oat kernel and shorter straw than the later varieties and usually test two or three pounds lighter per bushel; they make, however, a very good feed oat.

The following data on the four oat varieties recommended for the Upper Peninsula, are given in order that their relative merits might be better understood. In 1919, no co-operative work was attempted, so only the Station data are available for that year. During the past three years, over twenty varieties have been tested each year at the Upper Peninsula Experiment Station. A wide range in yield has been found. The four varieties recommended have consistently stood at the top of the list.

TABLE 13—OAT YIELDS IN THE UPPER PENINSULA.

Name	County	Variety								
		Wolverine—bushels			Worthy—bushels			Swedish Select bushels		
		1919	1920	1921	1919	1920	1921	1919	1920	1921
Upper Peninsula Exp. Station	Alger	75	130	38	69.5	128.1	39	68.9	124.9	35
E. J. Bergman	Delta	......	95	......	......	......	......	......	74	......
C. R. Millar	Schoolcraft	......	88.5	23.1	......	74	......	......	82.5	16.5
County Farm	Menominee	......	68	33	......	57.5	......	......	57.5	14.9
E. E. Stenson	Baraga	......	60	28.3	......	78.5	......	......	70	19.8
Poor Farm	Ontonagon	......	......	41.3	......	......	44.8	......	......	28.5
O. L. School	Houghton	......	......	33	......	......	......	......	......	26
Average years all test		75	88.3	32.8	69.5	84.2	41.9	68.9	81.8	23.5
3-year average all tests		65.4			65.2			58.1		
3-year average U. P. Ex. Sta.		81			78.8			76.3		

There is a question as to which of these three years approaches the normal season for oats in this territory. A careful study of the weather data for these three years and then a study of it over a period of years, tends to show that 1920 is more nearly a normal year than is either 1919 or 1921. Such being the case, the Wolverine, Worthy or Swedish Select would be a better variety than would an early oat like Iowa 103.

Fig. 12. Barley is well adapted to Upper Peninsula conditions. It is a very dependable crop for a concentrated livestock feed. The Wisconsin Pedigree is one of the best varieties.

BARLEY.

Wisconsin Pedigree—This is the common six-row white barley and is a very dependable sort. The Wisconsin Pedigree is a selection of Oderbrucker variety, made by the Wisconsin Experiment Station.

Michigan Black Barbless—This is a six-row black barley with smooth awns (beards). This is one of Professor F. A. Spragg's selections and has been giving very good results throughout the State when grown on a fairly fertile soil. It is a short-strawed type, and on lighter soils, quite frequently is so short as to be difficult to harvest. In the fields, this barley does not create a very favorable impression because the heads appear to be small. This is due to its short compact head, while the old type, like Wisconsin Pedigree is very loose and open, giving the appearance of a much larger head than it really is.

Michigan Two-Row—This is a two-row white barley, has a tendency toward a weak straw, which under our humid conditions, causes lodging on our more fertile soils.

TABLE 14—BARLEY YIELDS IN THE UPPER PENINSULA.

Name	County	Variety								
		Wis. Ped.			Michigan Black Barbless			Michigan-2-Row		
		1919	1920	1921	1919	1920	1921	1919	1920	1921
U. P. Experiment Station	Alger	16.2	50	32.3	20	53.9	45.4	17.1	61.2	40.3
E. J. Bergman	Delta	......	52	......	......	64.5	......	......	53.5	......
Erickson Bros	Marquette	......	23.5	......	......	41	......	......	33.5	......
C. A. Cassagranda	Iron	......	30	......	......	60.5	......	......	57.5	......
Poor Farm	Ontonagon	......	......	16.5	......	......	16.5	......	......	25.3
Whitney Farms	Menominee	......	......	8.8	......	......	9.9	......	......	8.8
I. E. Pawley	Schoolcraft	......	......	16.5	......	......	16.5	......	......	17.6
Tom Carey	Dickinson	......	......	16.5	......	......	2.2	......	......	19.8
Average all tests by years		16.2	38.9	18.1	20	55	22.1	17.1	51.4	22.4
Three year average		24.4			32.4			30.3		
Three year av. U. P. Exp. Sta.		32.8			39.8			39.5		

A careful study of these data shows that in all tests, whether taken individually or as an average, these three varieties have ranked as follows: Michigan Black Barbless, first; Michigan Two-Row, second; and Wisconsin Pedigree, third; except in two instances, when the Black Barbless and Michigan Two-Row were reversed. It is not desirable at this time to recommend one of these varieties over the other, but every community should have a carefully managed barley demonstration to determine which is best for their conditions and this should be supplemented by data obtained from fields. Barley is becoming more and more the important grain crop of the section, and we should grow the best.

FIELD PEAS.

This crop as a feed for livestock is destined to be one of the most important in the section. There is no particular variety that has as yet shown marked superiority over all others, neither has there been any special effort placed on producing seed of high quality. During three years of testing at the Upper Peninsula Experiment Station, the colored sorts such as Chang, English and Belgian varieties have outyielded the white sorts under the name of Canada Field.

MISCELLANEOUS SPRING GRAIN CROPS.

Buckwheat—This crop is not particularly adapted to the section though quite an acreage is grown each year. The climate is quite favorable to the growing of this crop except that it is very susceptible to frosts and since light frosts sometimes occur during the growing season it puts this crop in the uncertain class.

Speltz—This crop is quite frequently grown as a substitute for oats or barley. It is not to be recommended where oats and barley do well, but on ground too light to produce oats it has some value.

Spring Rye—This crop is adapted to the section and can be grown quite successfully. The fall sown rye, however, is much higher in quality and production so that very little spring rye is sown in the area.

FALL SOWN GRAINS.

The culture of the fall-sown grains determines very largely whether or not the crop is successful.

EARLY PLOWING ESSENTIAL FOR GOOD SEED BED.

Early plowing to enable the early preparation of a good seed bed is one of the important factors in fall grain production, but it is a very difficult thing to do under present cropping conditions in the Upper Peninsula as practically all of our crops are harvested too late to permit of a fall grain seed bed being prepared.

Summer-fallowing is one of the best methods. In addition to giving an excellent seed bed, it permits a very effective method of controlling quack grass. Early fall plowing of hay meadow is also a very good method of obtaining a good seed bed. To be effective the hay must be cut as early as possible. The plowing of a grain stubble will permit of a fair seed bed preparation. It has the disadvantage of allowing a grain crop to follow grain which is a very poor farm practice. In either of the systems followed in preparing the fall seed bed the thorough use of the harrow, disk and roller can not be over emphasized.

EARLY PLANTING IMPORTANT.

It is very necessary to plant the fall grains at the proper time if good results are to be secured. August 20 to September 5 is the time recommended for this section of the State. Grain seeded at this date is less apt to winterkill and yields a better quality of grain, than does the late seeded grain.

TABLE 15—THE EFFECT OF DATE OF PLANTING ON THE YIELD OF WINTER WHEAT.

Date of planting	1920 Bushels per acre	1921 Bushels per acre	Two year average
August 18-24	36.5	6.4	21.5
August 25—September 1	27	11	19.0
September 2-8	21	8.9	15.0
September 9-14	16	3.6	9.8
September 15-21	10	2.2	6.1
September 22-28	12.5	1.4	7.0
September 29—October 5	10.5	2.1	6.3
October 6-13	16	2.2	9.1
October 14-21	12	2.2	7.1
October 22-29	9.5	10.5	10.0
October 30—November 5	5	8	6.5

Fall wheat should not be grown unless it can be planted at the proper time on a fertile well-prepared seed bed. Fall rye is a very successful crop and should be encouraged.

The rate of sowing will vary with the time of planting and the fertility of the soil. In general the rate recommended in the Upper Peninsula for a winter wheat is five to seven pecks per acre, and for fall rye is four to six pecks per acre.

The use of the fanning mill to insure clean seed, the use of seed treatment to control smut and the germination test is as important as in the treatment of spring sown grains.

VARIETIES.

Winter Wheat—There are two qualities which a fall wheat variety to be successful in the Upper Peninsula must have, they are (1) winter hardiness and (2) ability to withstand or evade rust epidemics.

Considerable experimental work has been done with winter wheat but as yet no outstanding variety has been discovered. The results this past year gave a favorable impression of Kanred, a Kansas variety of the Turkey Red type which is proving itself quite winter hardy and also resistant to rust but has a tendency to lodge under real favorable conditions. Red Rock, one of Professor F. A. Spragg's introductions, has proven to be quite winter hardy but has not been able to withstand rust attacks.

Winter Rye—Rosen rye developed by Professor F. A. Spragg at the East Lansing Station is the outstanding variety of the Upper Peninsula. All comparative tests over the peninsula and at Chatham sub-station have given Rosen a big lead over common varieties. Henry Berquist, Stephenson, in 1918 obtained 43 bushels per acre with Rosen. Henry Lukkarinen, Marquette county, in 1918 obtained 30 bushels per acre from Rosen and only 22½ from Common.

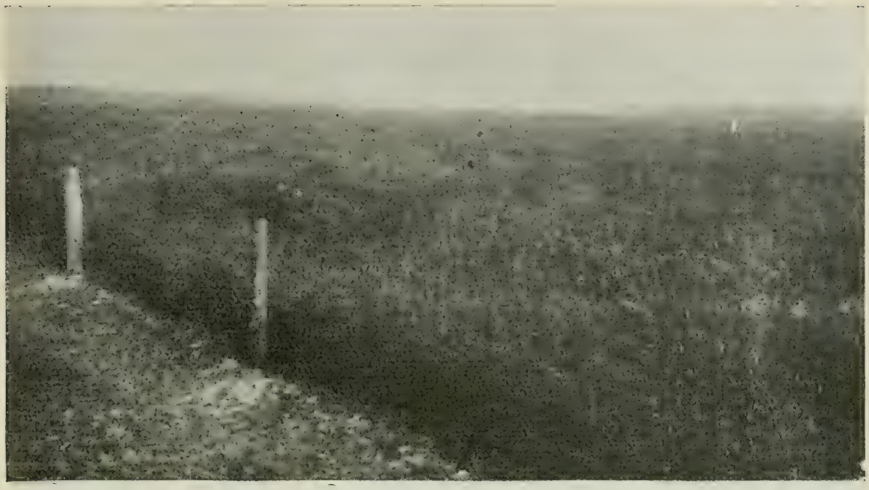

Fig. 13. Red Rock, a hardy, winter wheat has done well on the superior clay soils of Chippewa County.

TABLE 16—YIELDS OF ROSEN RYE DEMONSTRATIONS IN MENOMINEE COUNTY, 1917.

Demonstrator	Amount sown	Amount harvested		Increase of Rosen over common Bu.
		Common Bu.	Rosen Bu.	
C. E. Thorpe	1 bushel	9	13½	4½
Gust Theurkauf	1 bushel	12	16	4
Otto Staaleson	1 bushel	18	27	9

These are not necessarily typical yields but go to show the comparative results when the two are grown in competition.

FORAGE CROPS ADAPTED TO THE SECTION.

The forage crops of the Upper Peninsula can be classified as pasture, hay, silage and root crops.

The quanity, quality, and availability of the forage crops of a given section will usually determine its adaptation to live stock. It is possible to ship in concentrates but it is very essential to have a local supply of forage feed crops.

PASTURE.

Cut-Over—In its present stage of development there is an abundance of cut-over pasture land available in the Upper Peninsula. These cut-over lands have become seeded largely to clovers, timothy and June grass, thus making a very desirable pasture mixture.

Permanent—Many farmers will acquire more stump land than they will clear up for several years. This stump land will afford excellent

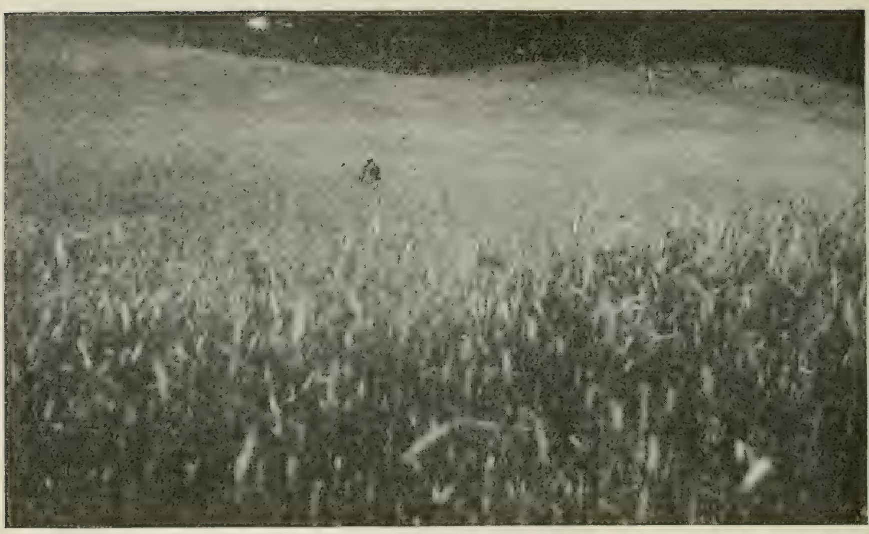

Fig. 14. Rosen Rye has proven itself to be the best yielding rye for the Upper Peninsula.

permanent pasture and the use of it for pasture will keep down second growth, permit the old stumps to rot and thus be a factor in clearing up the farm.

Practically every farm will have a certain acreage that is unsuited for cultivation, and such fields can best be utilized as permanent pasture.

TABLE 17—SEEDING RECOMMENDATIONS FOR PERMANENT PASTURE.

Upland:		Lowland:	
Red Clover	2 lbs.	Alsike Clover	2 lbs.
Alsike Clover	1 lb.	White Dutch	1 lb.
White Dutch	1 lb.	Sweet Clover	1 lb.
Alfalfa	1 lb.	Red Top	2 lbs.
Timothy	2 lbs.	Timothy	2 lbs.
June Grass	3 lbs.	June Grass	2 lbs.
Orchard Grass	2 lbs.	Orchard Grass	2 lbs.
Total, per acre	12 lbs.	Total, per acre	12 lbs.

HAY.

A wide range in choice of hay crops is made possible in the Upper Peninsula because of the adaptation of a large number of legumes and grasses suited for hay purposes. In selecting the hay crop to use, considerable attention should be given to selecting one that will give a maximum tonnage and yet be of good quality. The usual practice is not to use any one hay crop but a mixture of several.

Red Clover—This is probably the most widely grown and important legume hay crop in the section. It is adapted to well-drained upland soils comparatively high in lime content. There are two commercial varieties, medium red and mammoth red. The medium red is usually a little finer stemmed, and blooms about two weeks earlier than the mammoth. Occasionally a crop of hay is taken off and a crop of seed produced with the medium red while the mammoth is too late for this practice. For Upper Peninsula conditions there is not much difference which of these varieties is used. It is claimed the mammoth has the advantage of being longer lived, in fields where the seeding is left over two years this might be an advantage.

Alsike Clover—This clover is playing an important role as a hay crop in the Upper Peninsula. It will tolerate a soil lower in lime content than will the red clover, is also able to withstand more moist conditions, and this makes it desirable for low bottom land meadows. Alsike clover is, however, primarily adapted to a well-drained soil high in lime, under which conditions it will produce its best.

In 1919 L. R. Walker, County Agent in Marquette county, carried on a demonstration at Republic on an upland sandy loam soil under fairly uniform conditions in which he obtained the following results with medium red and alsike clovers:

Medium red, 5746 lbs. per acre.
Alsike, 4600 lbs. per acre.
Difference in favor of red, 1146 lbs. per acre.

Regarding the merits of these two clovers it is difficult to say which is better for a given section without local trials.

Fig. 15. Alsike and red clover on the test plot of County Agricultural Agent L. R. Walker in Marquette County.

A common practice and a very sound one is to seed a mixture of red and alsike together, then each will succeed best in its own environment. It is quite frequently the case that part of a meadow is best suited to red while the remainder will do best if seeded to alsike. The usual method of seeding is to use a mixture of two parts of red clover to one of alsike.

Alfalfa—This is a hay crop whose adaptation to the Upper Peninsula has not as yet been fully established, though there are several well established fields throughout the area.

Sufficient work has been done with alfalfa to prove that it can be grown if proper attention is given to its cultural requirements and the securing of northern grown hardy seed.

Sweet Clover—is admirably suited to this section so far as growing the crop is concerned but its usage has been for pasture and green manure rather than as a hay crop.

Timothy—This is a non-legume hay and one has only to visit the great timothy hay region of Chippewa county to appreciate its place in Upper Peninsula Agriculture.

At the time when timothy hay received a premium as a great horse feed its place was probably undisputed but horses are on the decline and dairy cattle are on the increase. It is almost an impossibility to buy on the hay market of the Upper Peninsula pure legume hay, yet that is what our feeding experts tell us is required for all classes of livestock other than horses. Why not adapt our farming to changed conditions, produce only enough timothy hay for a limited horse feed market and grow more clover or other legumes for our own livestock?

TABLE 18—COMPARATIVE FEEDING VALUE OF STANDARD HAY CROPS*.

Crop	Total dry matter 100 lbs.	Digestible nutrients in 100 lbs.			
		Crude protein	Carbohydrates	Fat	Total
Red clover	87.1	7.6	39.3	1.8	50.9
Alsike	87.7	7.9	36.9	1.1	47.3
Alfalfa	91.4	10.6	39	0.9	51.6
Sweet clover	91.4	10.9	38.2	0.7	50.7
Timothy	88.4	3.0	42.8	1.2	48.5

*"Feeds and Feeding" by Henry and Morrison.

Bluejoint—This native grass of the sloughs and low grounds of the Upper Peninsula makes a good grass roughage. Its feeding value is nearly equal to that of timothy if it is harvested at the right stage. It should be cut just before bloom, for if allowed to get too ripe it loses in palatability.

EMERGENCY HAY.

Emergency hay crops serve a very useful purpose under many conditions. Quite frequently something happens to the regular seeding and the hay meadow is reduced for that year. Oftentimes the herd is increased without having had an opportunity to increase the meadow land. It is for such conditions as these that we recommend the use of emergency hay crops.

Peas and Oats—Use a 50-50 mixture by measure of the two seeded at the rate of two and one-half bushels per acre. This mixture is especially good for the heavier soils. Care should be exercised in choosing varieties that will mature at about the same time. Wolverine or Swedish oats with Chang field peas make a good combination.

Vetch and Oats—Use one bushel of oats to twenty pounds of hairy vetch per acre. This mixture is better than peas and oats for lighter soils and even on some of the heavier soils it is preferred because the vetch is naturally a drier plant and is not so difficult to cure for hay.

Grains, Cut Green—Farmers sometimes cut oats or some other cereal grain for hay. This is not considered a good practice generally, for legumes added to the grain would increase the tonnage and quality over the grain alone.

Sudan Grass—The character of the season will have a great deal to do with the success of this crop. It is primarily adapted farther south, although in seasons such as 1921 it did exceptionally well because of the warmer weather. Twenty to thirty pounds per acre is the usual rate of seeding.

Millet—The millets are a favorite quick-growing, short season hay crop adapted to practically all conditions in this section. They will not produce as heavily nor are they as desirable for feeding as some other of our annual hay crops. Common and Hungarian are two of the better varieties for Upper Peninsula conditions.

TABLE 19—FEEDING VALUE OF ANNUAL HAY CROPS*.

Crop	Total dry matter 100 lbs.	Digestible nutrients in 100 lbs.			
		Crude protein	Carbo-hydrates	Fat	Total
Peas and oats	83.4	8.3	37.1	1.5	48.8
Oats and vetch	84.3	6.9	37	1.4	47.1
Grain cut green	88.0	4.5	38.1	1.7	46.4
Sudan grass hay	90.0	2.7	45.4	0.7	49.7
Millet	85.7	5.0	46.0	1.8	55.0

*"Feeds and Feeding" by Henry and Morrison.

SILAGE CROPS.

The place of silage crops in the Upper Peninsla has been established beyond question for those farmers who are keeping dairy herds of any size. The small farmer just getting started with a few cows will probably do better to obtain his winter succulence from root crops.

Peas and oats have been the most reliable silage crop over the greater portion of this area. Corn has been successfully grown in several of the southern counties and in local sections that are protected from frosts. In the last three years a new crop, sunflowers, has come into prominence that bids well to replace both corn and the peas and oats, except where corn has been proven to be especially well adapted.

SUNFLOWERS FOR SILAGE.

This crop is grown in very much the same way that corn is produced for silage.

PLANTING.

On those farms where corn planters are in use, special plates can be made to handle sunflower seed very satisfactorily. On many farms where corn has not been a regular crop and no planter is available the ordinary grain drill will give satisfactory results if part of the holes are plugged to obtain the proper spacing of rows.

Experiments conducted at the Chatham Experiment Station on time of planting indicate that early plantings from May 15th to June 1st are better than later plantings. Six to 8 pounds of seed per acre in rows from 30 to 36 inches apart will give maximum yield and best quality of silage.

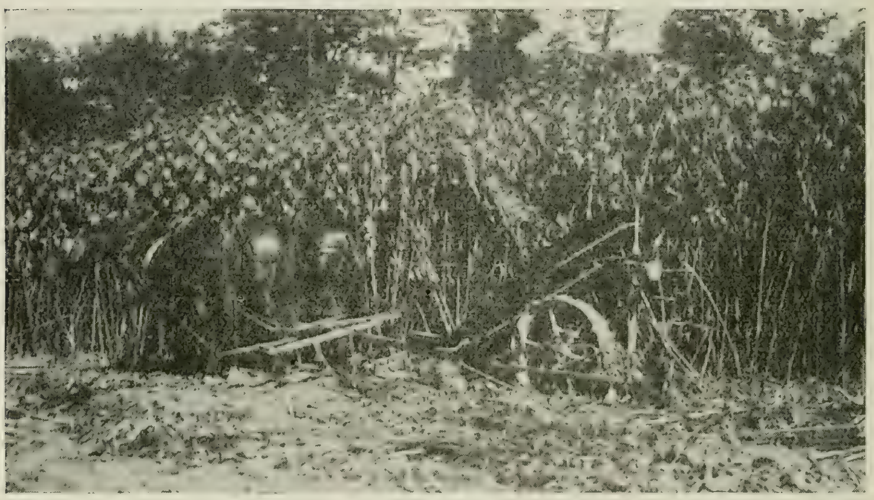

Fig. 16. Corn harvesting equipment is also very satisfactory in harvesting sunflowers.

If help is available and maximum tonnage is desired, a good plan is to seed 8 to 10 pounds per acre and then when the plants are 5 or 6 inches high go through with a hoe and block out so as to have a plant standing every 6 to 8 inches in the row.

The Mammoth Russian sunflower is the variety recommended by the Station at the present time.

TIME TO CUT FOR SILAGE.

Sunflowers should be cut for silage when the field is about 1-10 to 1-3 in bloom. This crop comes into maturity too irregular to base the time of cutting on a condition such as milk stage or dough stage. The condition of the field as a whole must determine the time to cut.

HARVESTING.

Ordinary corn harvesting machinery is quite satisfactory for the harvesting of sunflowers. At the Chatham sub-station a two-row sled was devised on a 2 x 4 runners with the front end 24 inches wide and 42 inches wide in the rear. Knives were made from an old crosscut saw and attached to the edges. Two men stood on the sled and gathered the cut stalks in bundles. These were laid at the side of the row where they were collected by wagons and hauled to the cutter about one-half day after cutting. Where the acreage grown will not warrant the expense of a corn harvester, this is an economical way of harvesting.

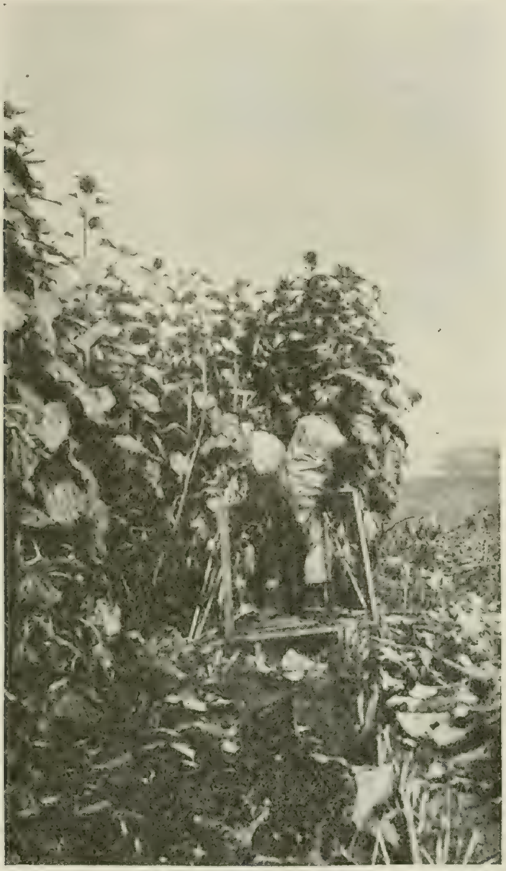

Fig. 17. Sunflowers, when properly handled and harvested make good silage. They are especially well adapted to sections in which corn is not adapted. This picture shows the sunflower sled cutting sunflowers.

CORN FOR SILAGE.

Corn should be grown only in those sections to which it is adapted. Corn to be adapted must do more than merely germinate and grow, it must mature to a stage that will make good silage.

Plant corn as early as possible and still evade spring frosts. This will vary with different locations but will be somewhere around June 1 to June 10.

Corn for silage should be planted at the rate of 6 to 8 quarts per acre in rows 30 to 42 inches wide. Use the heavier rate of planting on the more productive soils, decreasing the rate on the less fertile soils.

VARIETY TO USE.

In selecting a variety of corn, try to get one that will reach the proper stage of development during the growing season of that section. Varieties that are most commonly grown in the Upper Peninsula are Wisconsin No. 8, Wisconsin No. 12, Wisconsin No. 25, Minnesota No. 13, Northwestern Dent and the Flint varieties.

HARVESTING.

The method of harvesting corn for silage is well understood. But the stage of development at which to harvest requires some attention. Farmers' bulletin No. 578, U. S. D. A. gives the following comparative value of ear vs. stover corn:

TABLE 20—YIELD OF DIGESTIBLE MATTER IN CORN.

Constituent	Yield per acre—pounds		
	Ears	Stover	Total crop
Protein	244	63	307
Carbohydrate	2,301	1,473	3,774
Fat	125	22	147
Total	2,670	1,558	4,228

A study of this table shows that the ear is the important factor in determining the feeding value of a crop of corn. These figures probably could not be duplicated in the Upper Peninsula, but the relative value between ear and stover will hold irrespective of total yield.

The following table taken from the same bulletin gives the weight of protein, carbohydrate and fat produced by an acre of corn at two stages of growth, the milk and the glazed stage.

TABLE 21—YIELD OF PROTEIN, CARBOHYDRATES AND FAT FROM AN ACRE OF CORN AT DIFFERENT STAGES OF MATURITY.

Constituent	Yield per acre	
	Milk stage, pounds	Glazed stage, pounds
Protein	478.56	643.36
Carbohydrate	3,705.26	5,965.67
Fat	226.73	298.49
Total	4,410.55	6,907.52

This data has a very important bearing on corn production in the Upper Peninsula. At many county fairs samples of corn are exhibited from 14 to 16 feet high. Many of these samples will only have reached the silk stage while the best will not have passed the milk stage. Grow adapted varieties if you are in a corn section, otherwise grow sunflowers.

PEAS AND OATS FOR SILAGE.

The usual method of sowing peas and oats for silage is to use a 50-50 mixture, that is, one bushel of peas to one of oats, then sow from two to three bushels per acre of this mixture, the amount depending on the fertility of the soil. At the Chatham sub-station two and one-half bushels were found to be the best rate.

VARIETIES.

Use adapted varieties of both peas and oats and choose varieties that will mature at about the same time. If an early oat is used with a late variety of peas the oats will be shattering before the peas are ready to cut. Medium early oats such as Swedish select or Wolverine with such varieties of peas as French, June, Chang, English grey or Belgian will give very good results.

HARVESTING.

This crop should be cut when the oats are in the dough stage if the proper varieties have been used, the peas should be well formed in the pods but not too mature.

Peas and oats are a crop difficult to harvest. The cutting is done with a mowing machine. The crop is then usually bunched or windrowed by hand, if a horse-rake is used there is to much danger of picking up stones that might cause serious damage to the ensilage cutter. After bunching it is hauled directly to the cutter and ensiled.

CLOVER FOR SILAGE.

This crop is not usually used for silage though occasionally a crop becomes damaged by rain and is put in the silo. As a silage crop one could not afford to grow clover, but often a crop of clover can be saved in this way that would otherwise be spoiled.

GENERAL CONCLUSIONS ON SILAGE CROPS.

TABLE 22.—THE FOLLOWING TABLE SHOWS THE ANALYSES OF THE FOUR CROPS USED FOR SILAGE IN THE UPPER PENINSULA.

Kind of silage	Composition of silage, per cent					
	Moisture	Protein	Fat	Crude fiber	Nitrogen free extract	Ash
*Corn, normal	72.35	2.52	0.82	6.20	16.93	1.13
†Corn, immature	79.00	1.90	0.60	5.80	11.30	1.40
*Sunflowers	76.35	2.66	0.84	7.14	11.16	1.85
†Peas and oats	72.50	3.80	1.30	9.60	10.00	2.80
†Clover	72.20	3.70	1.1	9.00	11.50	2.50

*A. J. Patten, Mich. Exp. Station Quarterly, Vol. 3, No. 4.
†Feed and Feeding, Henry and Morrison, Table I Appendix.

A study of the preceding table shows that normal corn silage and sunflower silage have very nearly the same chemical analysis and that sunflowers show a much better analysis than does immature corn. When we consider the fact that much of the corn going into the silos in the Upper Peninsula is immature, it can be readily seen that sunflowers have a place in our system of agriculture. A careful study of all the analyses will show that the peas and oats and also the clover silage, pound for pound, is higher in analysis than either corn or sunflowers but the fact that sunflowers will yield from three to four times as much silage to the acre as either of these crops gives it another big advantage.

ROTATION AND FERTILIZATION OF FIELD CROPS IS ESSENTIAL TO PERMANENT AGRICULTURE.

Proper rotation and fertilization have been recognized as consistent with good farming methods for a great many years. And yet it has been only in the past few years that farmers have realized the penalty for not following such a system.

In the Upper Peninsula a few sections are beginning to show decreased crop yields because the soil fertility is being robbed. In the great hay section of Chippewa county, where the practice for years has been to sow oats seeded with timothy hay and cut the hay for the next five to twenty years, then to plow it and again sow to oats seeded with timothy, to be cut as hay for another five to twenty years, the natural fertility of one of the richest soils in the state is being destroyed. In certain other sections the practice is to remove several small grain crops one after the other, thus removing the soil fertility by means of grain crops. On many of these farms the manure, where there is any, is placed on the field or fields nearest the barns with no attempt to cover the entire farm.

Such farming practices as these can continue for some time on soils naturally high in organic matter and rich in the elements of fertility, but when applied to one of the less fertile types, the fertility is soon destroyed. This is illustrated by the run-out condition of the soil of the Wetmore area in Alger county.

THE PRINCIPLES OF A GOOD ROTATION.

The various classes of farm crops, by virtue of their different types of root systems and their different composition, do not remove the same elements in like amounts or from the same level in the soil, therefore, by changing from field to field with different classes of crops, a beneficial effect is apparent as compared to the one crop system. The hay crops because of their elaborate root system and sod formation aid in the upkeep of the organic matter of the soil. The legumes because of their ability to store nitrogen in the soil should be included in the rotation. A cultivated crop should be included to aid in weed control and to aerate the soil properly.

A rotation to meet these requirements would include the following:

First: A legume hay crop (clover, alfalfa, sweet clover)
Second: A cultivated crop (potatoes, sunflowers, root crop, corn, sugar beets)
Third: A small grain crop (oats, barley, wheat, rye).

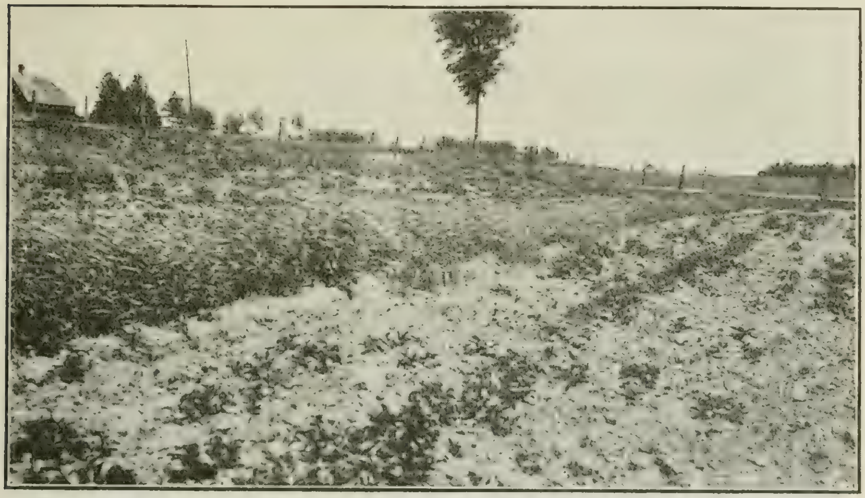

Fig. 18. Summer fallowing is advised where trouble is experienced with quack-grass. This also prepares excellent seed bed for fall grains.

WHEN TO APPLY LIME, MANURE AND FERTILIZERS IN THE ROTATION.

Lime where needed should be applied in fitting the seed bed the season preceding the hay crop. Manure should be applied as a top dressing on the meadow or applied to the sod the season preceding the cultivated crop.

FERTILIZERS.

Complete fertilizers if used should be applied to the sugar beet or potato crop. Acid phosphate usually gives good results and should be applied once every three or four years. This can best be done on the small grain or hay crop at the rate of 200 to 400 pounds per acre.

POTATO CULTURE.

The potato is the most important and valuable cash crop for the average farmer in the Upper Peninsula. Climatic and soil conditions of this section insure not only a good yield of this crop but also a potato of superior quality. Growers are being urged to make an effort to help standardize varieties and improve the "Cloverland" potato.

PREPARATION OF THE SEED BED.

Potatoes should be planted on sod land, as a general method. They constitute about 70 per cent of the total acreage of crops grown on newly cleared land, which is well suited to the production of this crop.

When a three or four year rotation is practiced, the potato crop is usually followed by oats, barley, or spring wheat and seeded down to clover and timothy. After the hay is removed a coat of manure should be applied and the second growth of grass plowed under in the fall.

Fig. 19. A portion of a seven acre field of potatoes on the farm of Chas. Salewsky, Menominee.

Spring plowing is practiced on some of the lighter soils, but on most soils fall plowing generally gives the best results. In the spring the ground should be disced and harrowed until a good seed-bed is secured. If the sod is spring plowed, it is well to disc it before plowing as this breaks up the sod into small pieces that will mix through the furrow slice and favor the supply of capillary water coming up to the surface. If clover sod is not available, then top-dress with well rotted manure and disc thoroughly before the manure has time to dry out. Well rotted manure is not as apt to cause potato scab as is fresh manure.

TIME OF PLANTING.

The time of planting has a distinct influence on the crop to be produced in this section, where it is necessary to have the entire growing season properly to develop and mature the crop.

TABLE 23—DATA SHOWING THE EFFECT OF DATE OF PLANTING ON THE YIELDS OF THE LATE VARIETIES, GREEN MOUNTAINS AND RURALS.

Date of planting	1920		1921	
	Green Mt., bu.	Rurals, bu.	Green Mt., bu.	Rurals, bu.
May 19	363	384	374	279
May 26	393	409	3 days rain	
June 2	350	313	272	238
June 9	326	326	237	208
June 16	319	241	257	277
June 23	226	257	221	215
June 30	156	142	152	170

The percentage of No. 2 potatoes increased very much after June 16th planting so that June 30th gave only about 50 per cent No. 1's.

On account of the fact that the late spring frosts and early fall frosts are only 85 to 100 days apart, it is essential to plan the planting so as to have the potatoes coming up a few days after the danger of the last killing frost in the spring, if we are to get maximum yields of matured potatoes.

RATE OF PLANTING.

TABLE 24—THE AMOUNT OF SEED NECESSARY TO PLANT AN ACRE OF POTATOES WITH VARIOUS SIZES OF SEED PIECES SPACED AT VARYING DISTANCES.

Rows Hills	Plants per acre	Bushels per acre seed—1 oz.	Bushels per acre seed—1½ oz.
3 feet x 3 feet	4,840	5 bu.	7½ bu.
3 feet x 18 inches	9,680	10 bu.	15 bu.
3 feet x 12 inches	14,520	15 bu.	22½ bu.
30 inches x 30 inches	8,969	9 bu.	13½ bu.
30 inches x 16 inches	13,068	13½ bu.	20 bu.
30 inches x 14 inches	14,934	15½ bu.	23 bu.

DEPTH OF PLANTING.

The depth of planting the seed potato depends on the character of soil and height of water table. On a light soil where level cultivation is practiced the potatoes can be planted 4 to 6 inches deep. On a heavier soil where the water table is near the surface and hilling is necessary for drainage in order to keep the tubers out of the water at digging time, the seed piece can be planted 2 to 3 inches deep and the plants gradually ridged up, the greatest ridging coming at the first cultivations.

METHOD OF PLANTING.

Two methods of planting potatoes are practiced, the hand method and the machine method. The hand method may be accomplished by marking out the field, then making the holes with a hoe and dropping the potatoes and covering as you go, or by a hand planter. Another method is by use of a shovel plow opening up a furrow, dropping the potatoes and then covering them up by hand. The machine methods are accomplished by the use of mechanical planters, the picker type or one-man planters, and the two-man planter. On purely commercial production for table stock, the picker type planter may have the advantage, while for the grower of fancy or seed potatoes that wants 100 per cent stand so as to have uniformity in tubers produced, the two-man type may be the best.

Fig. 20. A twenty acre field of potatoes on the Clearman Farms, Cornell, Delta County, July 29, 1919.

CULTIVATION.

Whether potatoes are cultivated before plants are up or after plants are up, does not make an appreciable difference in yield. It does, however, make a big difference in the labor cost of controlling the weeds. The method used is occasionally to run a spring-toothed harrow lightly over the potatoes from the time they are planted until they are well through the ground. Only a few plants are killed and at present it is the most satisfactory practice of early cultivation, although some loss of plants is experienced.

TABLE 25—DATA FROM A THREE-YEAR PERIOD SHOWING THE VALUE OF THE DIFFERENT METHODS OF CULTIVATING POTATOES.

Methods of cultivation	1919 bu. yield per acre	1920 bu. yield per acre	1921 bu. yield per acre	3 year av. yield per acre
Deep to shallow	143	393	287	274
Shallow to deep	119	371	237	242
Cultivated before plants are up	122	403	331	285
Cultivated after plants are up	143	421	320	295
Hilling	121	364	291	258
Flat culture	147	394	315	285

The methods followed were such as would show the advantage or disadvantage of the different methods of cultivation used in the Upper Peninsula. The deep to shallow method was to start the early cultivation deep and close to the plants when they are small, and work to a very shallow or mulch cultivation as the plants developed to full size.

In the shallow to deep method of cultivation a shovel plow is used at the last cultivation, usually when plants are in blossom. At this time the earth is winged up around the plants in ridges, supposedly to keep the potatoes from sunburning. Where there is soil deep enough to place the seed piece three or four inches below the surface of the ground, there is no need to hill unless the soil is heavy and drainage is desired in order to keep tubers from rotting. Potatoes sunburn usually because of diseased condition that prevent the tubers from developing normally.

The hilling and flat culture methods are used in different sections. One objection to the hilling method is that in dry years the ridge has a tendency to dry out much more quickly and produce a smaller crop, where the potatoes are extremely ridged from early in the season.

SEED TREATMENT.

The seed treatment experiments would indicate that the corrosive sublimate treatment gives the most satisfactory results of all treatment so far used. The comparisions have been made for three years with corrosive sublimate, formaldehyde and no treatment.

TABLE 26—A REPORT GIVING THE RESULT OF VARIOUS POTATO SEED TREATMENT METHODS OVER A THREE YEAR PERIOD.

	1919 Bushels per acre	1920 Bushels per acre	1921 Bushels per acre	Average Yield per acre
Corrosive sublimate	162	394	336	297
Formaldehyde	135	324	293	251
Untreated	130	207	294	210

It might be said that by the use of corrosive sublimate the presence of the black scurf on the potatoes when dug was materially lessened and the infection of scab was reduced fully as much as with the formaldehyde treatment. From the results obtained we can therefore recommend the corrosive sublimate treatment, although it is much more dangerous to use for it is a deadly poison so that extraordinary precautions should be taken to keep it away from livestock and children. In brief, this treatment consists of dissolving 4 ounces of corrosive sublimate in 30 gallons of water and soaking the potatoes in this solution for 30 minutes. Detailed methods of treating seed potatoes can be secured in Special Bulletin No. 110, Michigan Agricultural College, East Lansing, Michigan.

CUTTING SEED.

The potato is not a true seed and can be compared to a green cutting or a section of the vine producing it. The best eyes on the potato are on the seed end and in most instances these eyes sprout first and give the strongest growth when the whole potato is planted. The other eyes often dry up and do not sprout at all. Small seed of sufficient size to be cut, should be split from seed end to stem end splitting the bud eye cluster. Larger potatoes should be cut in the same manner only cutting the half section into two or three pieces depending upon size. Seed pieces should be about the size of a hen's egg and have two eyes. Cut above the eye and diagonally to the center. Seed should be treated before cutting. It is well to cut seed ahead sufficiently long to allow healing over of wound before planting; this prevents loss of moisture in a dry, hot soil or quick rotting in a wet soil. It approaches the advantages obtained by using whole seed.

Size of seed piece is influential in giving the young plant a start much the same as the first milk of the cow gives a good start to the calf, so do not be too economical on use of seed. If soil conditions are just right, potato peelings will grow but those conditions prevail in only one out of a thousand cases. Seed pieces the size of a hen's egg or larger make for strong vigorous plants.

Our experiments with green sprouting show that it eliminates the potatoes that will not sprout and also gives a week to ten days advantage in its development, and that under ordinary conditions it holds this advantage throughout the growing season. It also insures a stand if the conditions are excessively wet or extremely dry.

SPRAYING.

The value of bordeaux mixture as a repellant for leaf hoppers and other insects, has been demonstrated during this past season, 1921. It requires, however, that the spray be applied with a high pressure outfit and with sufficient nozzles to completely cover the tops and bottoms of leaves and the whole plant. This spraying must be started when the potato stalks are from three to six inches high, and continued until the potatoes have reached maturity. Late fall spraying this year controlled early blight which in many instances, especially with the rurals, came and finished up the work of the leaf hoppers. Slight injury is done to the plants by these late sprayings, even though the wheels of the sprayer do run over many of the tops. The loss is not comparable to the loss that would occur if the spraying was not done. By adding arsenicals in the early sprays, the potato bugs, etc., can be kept down. High pressure sprays are however, very essential to complete control, sprayers capable of maintaining 150 to 200 lbs. pressure are none too good especially for the careful grower of certified seed potatoes. For detailed information relative to spraying potatoes, write to the Director, Michigan Agricultural Experiment Station, East Lansing, Michigan.

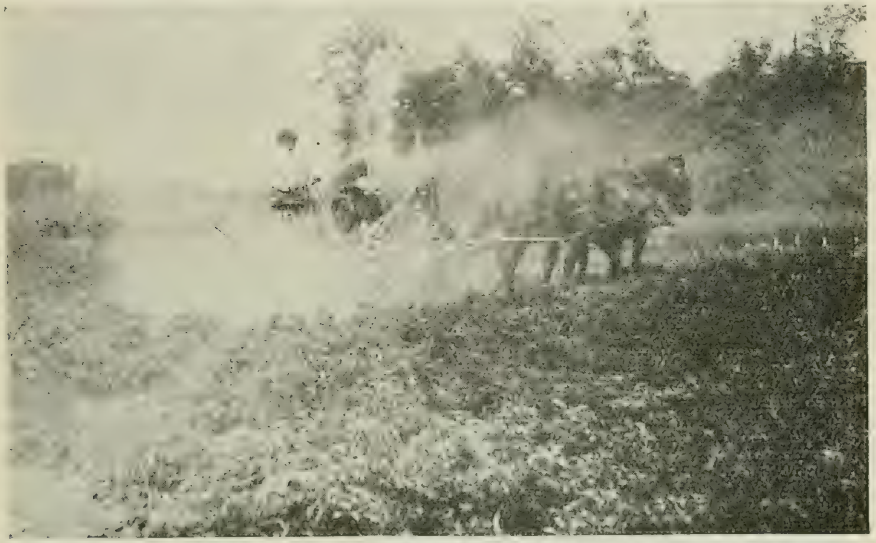

Fig. 21. An effective spray outfit for disease and insect control. Proper spraying increases the yield per acre of potatoes.

Hand sprayers or knapsack sprayers do very well for controlling potato bugs and such other insects as affect the potatoes by eating the foliage. When bordeaux is applied with these small sprayers it protects the plants to some degree, and makes for a stronger, healthier plant, and is considerably better than no spray at all but is of little value against the leaf hopper or blight disease when they occur in a serious manner. This type of sprayer is adapted to the small farm or garden spot.

HARVESTING.

The time of harvesting is influenced by the weather. The date of the first killing frost in fall is usually the time to commence digging operations. As long as the tops are green starch is being formed and the quantity of potatoes increased. Late potatoes may be benefited if left to lay for a week after early frost in order to harden up. Late potatoes for table use should be matured and in good condition when harvested. Immature potatoes are considered good seed stock but usually are difficult to separate from the vines and also have poorer cooking and keeping qualities than the mature kinds. Potatoes should be left to dry sufficiently long after digging so that dirt will clean off readily. This allows skin to toughen up and prevents the checking, cracking or bruising of tubers caused from handling when they are first dug.

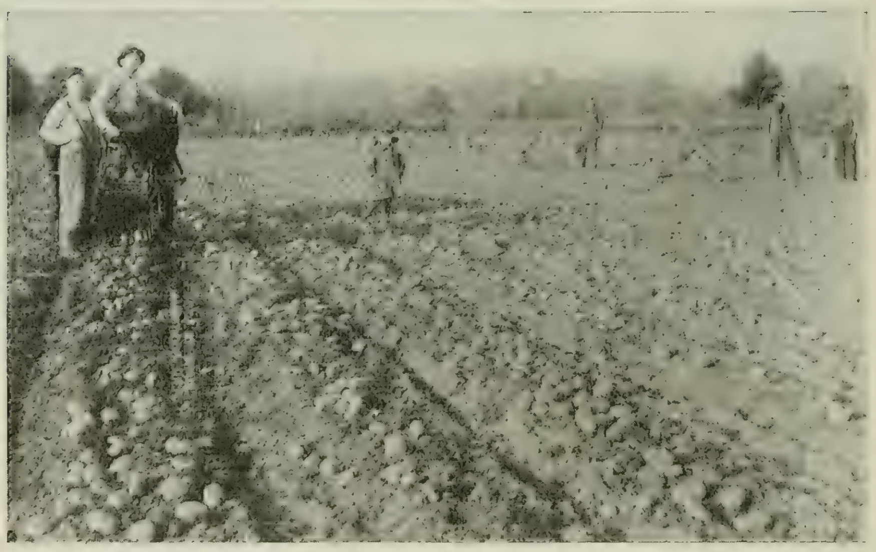

Fig. 22. Harvesting Rural Potatoes, farm of C. A. Miller, Schoolcraft County. A high yield of good quality potatoes may be grown in the Upper Peninsula.

The method of digging potatoes depends on size of field and development of the farm. Forks or hoes are the the common tool for potato digging on the majority of farms. Where several acres are planted the potato digger is being adopted. The elevator type machine where a steel nose runs under the row of potatoes and sifts the dirt through an elevator of parallel iron rods, dropping the potatoes behind is the type of digger most used. Plowing out the crop is generally considered extravagant and wasteful.

STORAGE.

Home storage forms about two-thirds of the storage space for potatoes produced in this section, (1) because of the short digging time in the fall between the time of first fall frosts and before dangerous freezing of potatoes in the field, (2) distance from market, the labor cost necessary to dig and haul to market at the same time is too great. The maximum economy is secured by marketing the crop more gradually, resulting in both fall and spring shipment. This condition necessitates winter storage and this is usually provided by a basement under the house, separate root-house built into side hill, or pit storage. Pit storage is usually only temporary for fall use in order to save handling when the potatoes are to be sold before severe winter weather sets in.

VARIETIES.

The principal varieties of potatoes grown are divided into two classes, early and late varieties.

The early varieties are the Irish Cobbler, Early Ohio and Bliss Triumph. The late varieties are the Rural, Green Mountain and Russet Burbank. In general it can be said that the green stem potatoes are more subject to disease and insect injury than the blue and brown stem.

The green stem varieties are the Green Mountain,, Burbank, Early Ohio and Bliss Triumph; the blue or brown stem varieties are the Rurals and the Irish Cobbler. Under similar conditions the Rural and Irish Cobbler hills need to be planted 12 inches apart in rows when the Green Mountain and Burbank need to be planted 15 inches to 18 inches apart.

The production of potatoes for use as table stock involves the production of a quality potato product that meets the demand of the commercial trade which wants a smooth shallow-eyed potato that is a good shipper, a good keeper and at the same time is a good eating potato. This combination is found in the Green Mountains and to a large degree in the Rural type especially the Russet Rural. Both these potatoes are adapted to the general market but when it comes to seed potato production we find that the Green Mountain has not the resistance to heat and drouth that the Rural has and so can not be raised for the outside seed trade, except for certain areas that has similar climatic condition to those found in the Upper Peninsula. The Rural type potato is successfully grown under a wide variation of climatic conditions. It stands the heat and drouth of the Corn Belt states better probably than any other variety. Thus for a seed potato proposition the White Rural or Russet Rural lends itself to the development of a large seed market.

The early varieties mentioned are used principally at present for the early home use before the late or main crop is developed.

The commercial value of these varieties depends upon the production of sufficient quantities so that carload lots can be shipped to the south for seed purposes to those sections that furnish our spring and early summer crops of early market potatoes. At present this market in the central west is being supplied by growers located principally in Wisconsin and Minnesota.

SEED IMPROVEMENT.

In order to promote the growing of better seed potatoes, work at the Experiment Station has been undertaken, (1), to eliminate plant disease, (2), to secure high yielding strains, (3), to maintain desirable types, and (4), to select those strains that will improve the general yield of potatoes.

Seed potatoes should be selected from healthy productive typical hills. The causes for decreased yields are due probably to the presence of Mosaic, Leaf Roll, or Curly Dwarf which should be removed from the seed plot. These troubles are undoubtedly transferred from diseased plants to healthy plants by insects such as leaf hopper, potato beetles, and other insects. The use of bordeaux mixtures and arsenicals can be used to repell and destroy such insects. Black Leg and Fusarium Wilt can be eliminated by rogueing, while Rhizoctonia (Black Scurf) and Scab can be controlled by treating the seed with corrosive sublimate. If these operations are followed carefully it will be possible to secure a much higher yield of potatoes.

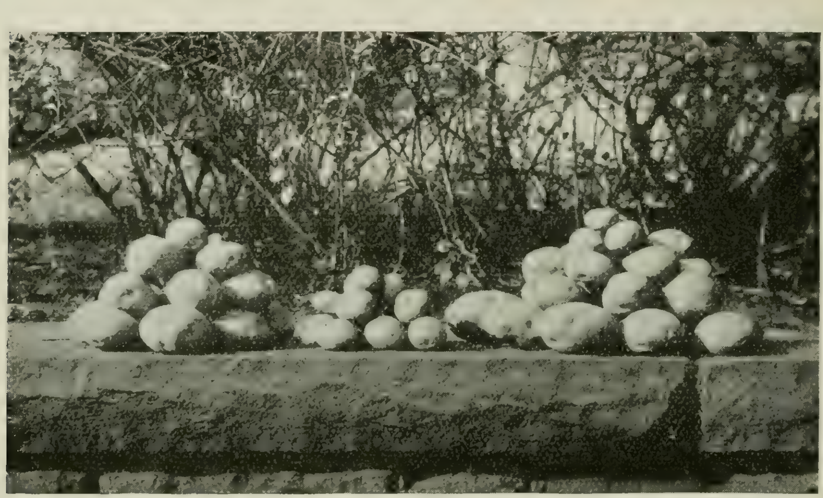

Fig. 23. Tuber unit work with potatoes at Republic. Each pile of potatoes is the resulting yield of a different potato, each of which when planted in the spring weighed eight ounces, and which was cut in four pieces and planted the same distance apart.

By selecting enough of those healthy hills showing a normal growth, having desirable type and producing good yields, and then planting them in a seed plot in a section of the general field, a sufficient supply of good seed can be secured for your general planting every year.

SUGAR BEETS*.

In certain sections of the Upper Peninsula, notably the southern portion, the sugar beet has long been considered one of the good cash crops for the farmer to grow. At Menominee is located one of the largest sugar factories in the State. This insures a ready and close market for all beets grown in the adjoining counties.

Any fertile, well-drained soil that will produce a good grain, corn, potato or clover crop, will, when properly handled, produce a good sugar beet crop. Clay loams, loams and fertile sandy loams are the soils best suited to the production of beets. Light sandy and marshy soils should not be selected.

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*Contributed by E. B. Hill, Assistant to the Director. Formerly County Agricultural Agent, Menominee Couny.

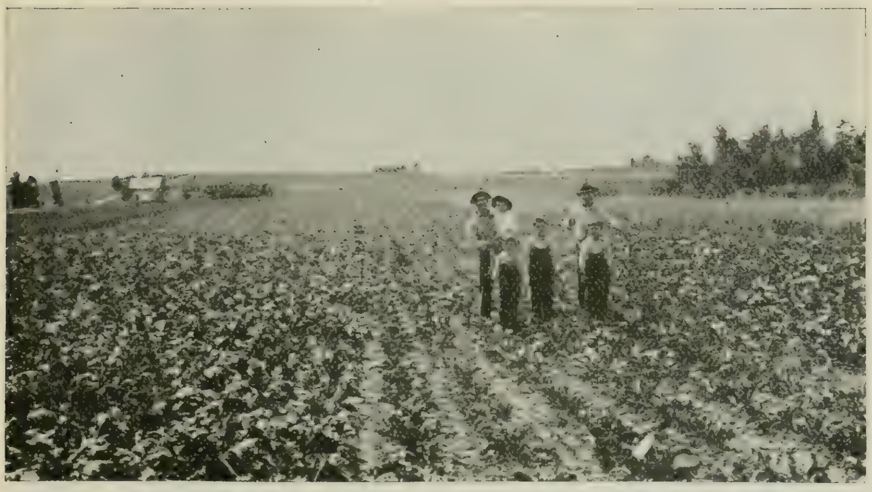

Fig. 24. A field of beets in Menominee County on the farm of Arthur DeCamp, Daggett. The soil and climatic conditions, combined with good transportation and markets of the southern portion of the Upper Peninsula, offer excellent opportunities for an increased acreage of the sugar beet crop.

The following crop rotation for beets gives the best results for this section: Clover sod or pasture followed by corn, potatoes or peas, to be followed by beets. After the beets a grain crop should be grown, which is usually seeded down with clover or alfalfa.

Fall plowing to good depth usually gives the best results in starting the soil preparation for this crop. This is followed by good surface preparation the next spring with the drag, disc and roller or cultipacker. Spring plowing should be done as early as the land is in condition to work well. Beets require a firm, well-worked seed-bed. Barnyard manure and commercial fertilizers are an aid in producing a larger yield per acre. Seeding at the rate of 12 to 20 pounds per acre is made during the month of May and fore part of June, depending on the season. The bulk of the beet crop is harvested during the month of October. The beet tops and leaves furnish excellent feed for livestock. The soil and climatic conditions of the southern and central portions of the Upper Peninsula offer excellent opportunities for safe expansion of the sugar beet crop.

OTHER ROOT CROPS.

The climate and soil conditions of the Upper Peninsula are very favorable for the production of root crops. They can be depended upon to produce a good supply of winter succulence. Equipment and storage conditions are available even on the new farm just being settled.

Root crops are adapted to quite a wide range of soil types; but the heavier yields and better quality of roots are generally produced on the sandy loams, loams, and clay loams. Yields of twenty tons per acre are not uncommon. In 1919 a period of high-priced labor, root crops were produced at the Chatham Sub-station at a cost of $3.68 per ton. The American purple top rutabaga is the most common variety grown.

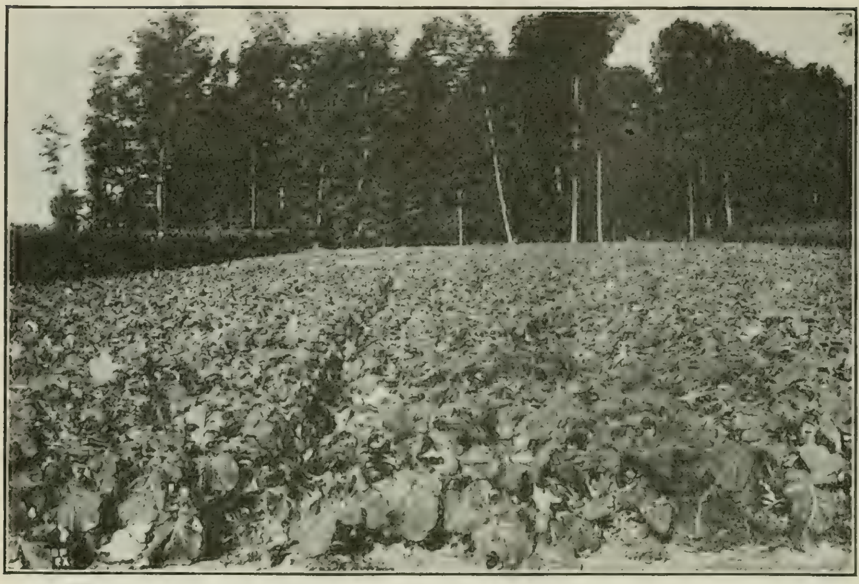

Fig. 25. The root crop is the best crop for the new settler to grow for a succulent winter feed. This field of purple-top rutabagas yielded 20 tons per acre in 1919.

The seed is small and requires a clean well-firmed seed-bed. One pound of seed per acre is sufficient if it can be uniformly sown. The usual practice, however, is to seed somewhat heavier and then block and thin to a plant every 4 to 6 inches, when the plants are up.

Root crops may be harvested by pulling and topping or by topping with a sharp hoe and then plowing out the roots.

Storage of roots can best be effected by utilizing a portion of the regular root house, potato cellar or by putting them in a pit. If they are to be fed as a part of the daily ration to livestock it is better to have them in a root cellar adjacent to the barn.

Opportunities for Livestock Production.

The Upper Peninsula is especially well adapted to the development of livestock. It has climatic conditions which favor long grazing seasons, soils capable of producing feed for winter use, large areas of comparatively cheap land for pasture purposes and an accessability to markets comparable with any section of the middle west.

Only about seven per cent of the arable land of the Upper Peninsula is under cultivation. A large percentage of the cut-over land has grown up to grass and undergrowth. The natural pasture is composed largely of blue grass, the clovers and timothy. On all of the limestone areas, the clovers grow in abundance shortly after the timber is removed, usually starting from the logging roads and spreading over the entire area. These facts indicate the possibilities of extensive livestock development in this large area of productive land.

The grazing season has a range of from five to seven months, depending upon location, class of stock, and the shortness to which the

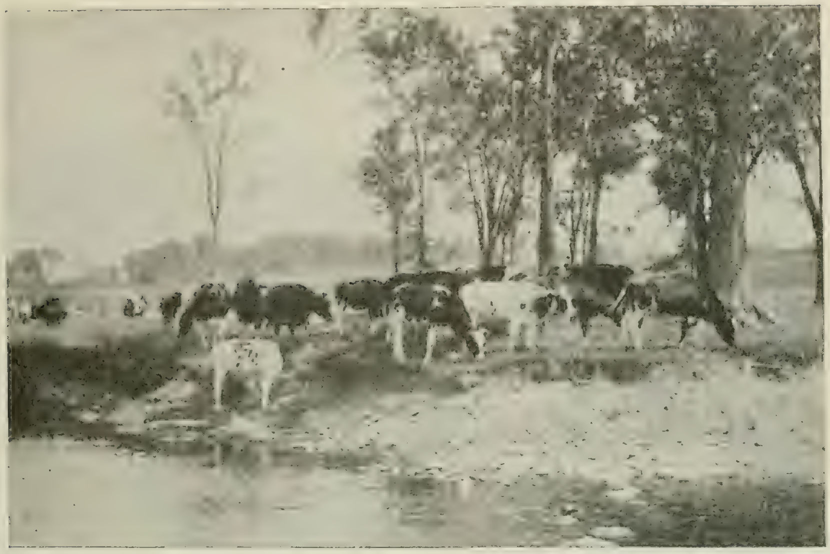

Fig. 26. Many fine herds of dairy cattle are to be found in the Upper Peninsula. Dairying is now, and will continue to be, the leading livestock industry of this section.

grass was cropped the previous season. Two-thirds of the yearly rainfall comes during the pasture season and this abundance of rainfall, together with the long days of summer, favors a luxuriant growth of nutritious vegetation through the spring, summer and fall. There are, in addition, cool nights and plenty of fresh cold water. These create a condition approaching the ideal for livestock development during the grazing season. The winters are usually cold with plenty of snow. A comparatively dry atmosphere maintains good health and appetites, where the housing conditions are right.

The three factors that influence the adaptability of different parts of the Upper Peninsula to livestock are, (1) soil types, (2) distance from shipping point, (3) size of farm.

The muck lands, swamp lands and all low, wet, swampy or poorly drained lands, are not adapted to sheep raising. The light sands or sand plains can be used to a limited extent for sheep, but the best results cannot be secured on these soils. The light sand and the extremely rocky, rugged areas are not adapted to cattle raising. The limestone loam, clay loam, and clay areas produce the best results with all classes of livestock.

The distance from shipping point or market will influence, quite largely, the class of stock produced on the farms. The distance depends not only on the mileage but also upon condition of roads and method of conveyance.

The class of livestock best adapted will often depend on the size of the farm. Dairy cows and poultry take the first place on the small farm. A small flock of sheep and a few hogs add additional income. This development takes place as the farm is cleared and sufficient winter feed can be produced to carry them through to pasture the following spring.

TABLE 27—DAIRY CATTLE IN THE UPPER PENINSULA 1920.

County	Total number	Calves under 1 year	Heifers over 1 year under 2	Cows and heifers 2 years or over	Bulls 1 year or over	Total value
Alger	2,453	610	427	1,322	94	$159,054
Baraga	4,012	972	643	2,234	163	220,399
Chippewa	10,475	2,755	1,342	6,222	156	562,317
Delta	10,710	2,694	1,690	6,021	305	601,519
Dickinson	3,866	843	658	2,264	101	226,428
Gogebic	3,710	959	550	2,118	83	254,058
Houghton	10,430	2,361	1,589	6,141	339	600,144
Iron	4,288	1,066	712	2,369	141	274,885
Keweenaw	366	89	50	216	11	23,026
Luce	1,363	402	208	730	23	103,275
Mackinac	3,022	676	469	1,807	70	159,318
Marquette	5,661	1,371	953	3,139	191	333,145
Menominee	20,875	4,753	3,312	12,298	512	1,024,771
Ontonagon	5,577	1,452	1,044	2,946	135	325,498
Schoolcraft	2,162	481	342	1,281	58	118,722
Total	88,970	21,184	13,989	51,108	2,389	$4,986,459

The class of stock kept on the large farms will depend somewhat on the owner's preference, the type of farming pursued and the factors of soils and markets which make dairy cattle, sheep or hogs most profitable.

DAIRY CATTLE.

Dairying is now, and will continue to be, the leading livestock industry of the Upper Peninsula. Some of the best herds of the entire country, and several of the highest individual milk and butter records have been produced in this section of Michigan. Practically all the dairy breeds are adapted to the Upper Peninsula—at present the Holsteins and Guernseys, however, predominate. The care and management of the dairy herd is based on the ability and the working knowledge of the owner to feed, house and improve the herd to get maximum results.

A cow gives her highest yields of milk when she has a plentiful supply of a well-balanced, palatable food, sufficient water and fresh air. These are the natural spring and early summer conditions, at which time milk is produced at the least cost. These conditions should be duplicated as nearly as possible during the remainder of the year.

SUMMER FEED AND CARE.

Pasture is the cheapest and best feed for the dairy cow during the summer months. This can be supplemented with a light grain ration

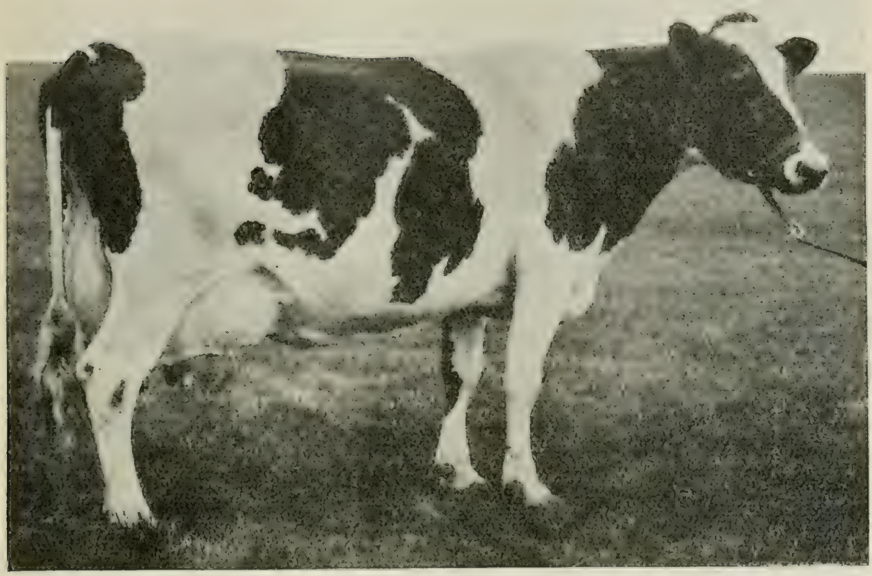

Fig. 27. Duchess DeKol Korndyke, a holstein cow owned by the Emblagaard Dairy, Marquette.

when necessary. Where possible, a pasture should be kept near the barn for late fall and early spring feeding, as it will shorten the winter feeding materially. It is always necessary to see that there is plenty of water and salt where the stock can reach it conveniently at all times. During the fly season, the stock should be sprayed with a good fly repellant at least twice a day. There are many good fly sprays on the market. A home-made spray that will be found effective, is the following: 12 oz. crude carbolic acid, 12 oz. turpentine, 12 oz. oil of tar, 12 oz. tannin, made up to 5 gallons with kerosene.

WINTER FEED AND CARE.

The soil of the Upper Peninsula can produce in abundance, all the feeds, with the exception of cotton seed and oil meals, that are necessary for the most economical production of dairy products.

In order to get the largest and most economical milk production, the feed must have palatability, variety, bulk, succulence and be well balanced. The cow must relish a food or she will not eat enough to give maximum production.

A mixture of grains is better than any single one, also two or three forms of roughage is preferable to one.

One of the ways of imitating early summer conditions when cows do their best, is to supply a succulent feed in the winter ration, such as silage or root crops. On farms where too few cows are kept to pay

Fig. 28. The new barn and the old. The County Agricultural Agent aided in the planning of the barn, through an agricultural meeting held in that neighborhood.

for the expense of erecting a silo, root crops should be grown. Rutabagas and mangels are the best crops for this purpose.

Silage is the cheapest and most easily handled of all succulent feeds. Sunflowers are rapidly taking first place as a silage crop, in parts of the Upper Peninsula, where corn cannot be grown successfully. Peas and oats, and clover make good silage but are more expensive than sunflowers. Sunflower silage has been fed with success at the Chatham Sub-Station, and on different farms of the Upper Peninsula during the past three years. Nearly all northern experiment stations are reporting favorably on this feed. The proper time for cutting sunflowers has been given under "Sunflowers." Page 519.

TABLE 28—THE COMPARATIVE ANALYSES BETWEEN CORN AND SUNFLOWER SILAGE*.

	Moisture, per cent	Protein, per cent	Fat, per cent	Crude, fibre, per cent	N. Free Ext. per cent	Ash, per cent
Sunflower Silage:						
Emblagaard Dairy, 1920...........	75.8	2.12	.81	8.15	11.18	1.94
U. P. Experiment Station, 1920....	76.9	3.20	.87	6.12	11.15	1.76
U. P. Experiment Station, 1921....	80.8	1.81	.65	6.61	9.08	1.71
Average mature corn.................	73.6	2.1	.80	7.8	12.9	2.1
Average immatured corn...............	79.1	1.7	.80	6.0	11	1.4

*Analysis by Prof. A. J. Patten, Chemical Section.

BALANCING THE RATION.

Balancing the ration, simply means combining the different feeds in such a way so there will be sufficient amounts of proteins, carbohydrates and fat in the ration to economically maintain the animal and support its proper functions. If there is an excess of any one of these factors, it will be largely wasted by passing through the digestive tract.

The rules for feeding grain are: (1) One pound of grain per day for each 3 or 4 pounds of milk produced, depending on the quality of milk and the roughage used, or, (2) One pound of grain per day for each pound of butter-fat produced per week.

HOUSING*.

The dairy barn should be conveniently located, well lighted and ventilated. Its location will depend upon the contour of the land, drainage and yarding space and its relation to other farm buildings.

The arrangements of the windows should be such that the maximum amount of sunshine can be admitted during the entire day. Concrete floors are the most sanitary and permanent. A rough finish proves the most serviceable and keeps the animals from slipping. Cork or plank over the concrete floor in the stalls is often advisable, especially when bedding is not plentiful.

Good ventilation is of great importance, but it is often neglected. A good dairy cow is the hardest worked animal on the farm. She is busy manufacturing feed into milk about ten months of the year, yet she is often, during cold weather, deprived of fresh air. Windows hinged at the bottom and opening at the top to let in fresh air, and a flue through the roof to carry out the foul air, will give fairly good satisfaction, in small dairies, but care should be taken to prevent drafts directly on the animals. A good ventilating system is a paying proposition in any barn. It should be adapted to the barn and be large enough for the number of animals kept.

CARE AND FEEDING OF DAIRY CALVES.

A large number of dairy cows have their producing possibilities greatly impaired when they are still calves, usually before they are two months of age. This trouble is indigestion, caused by (1) over-feeding and (2) an unclean, wet stall.

The dairy calf should have the first milk from its mother. This milk contains the colostrum that starts the digestive organs of the calf working normally. Allow the calf to run with the cow the first and second day after calving, then begin hand feeding. During the first two or three weeks give four to six quarts of whole milk per day, preferably in three feeds; morning, noon and night, then gradually change to skim milk. At this age the calf will start eating a little grain to take the place of the fat removed from the milk. A good feed is a mixture of bran, oats and cracked corn. Clover or alfalfa hay and a little silage are good feeds for calves. Water and salt should be kept before them at all times. Feed pails must be kept clean, as sour or dirty milk is apt to cause indigestion.

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*Complete plans for all farm buildings may be secured from the Farm Mechanics Dept. of the Michigan Agricultural College, East Lansing, Michigan.

Dry bedding and moderate feeding will aid greatly in taking the calf through the sensitive stage to where it is more resistant to disease. Calves take largely a liquid diet and consequently void comparatively large amounts of water and wet bedding causes more calves to scour than any other one thing, on the average farm.

Weakened vitality in many herds is often caused by dark, unventilated barns. Parasites, such as cattle lice, often do considerable damage. Where lice are present, the animals should be washed with a solution of coal tar dip or kerosene emulsion every two weeks. There are many preparations on the market for this purpose.

Fig. 29. Feeder steers making beef in Chippewa County. A view of the country between Sault Ste. Marie and Rudyard.

Milk fever is a disease often encountered at freshening time. In such cases fill the udder with air, by means of an air pump, forcing the air through sterilized cotton. A half pound of salts, dissolved in warm water, given as a laxative, will give relief. While the cow is unconscious, or partially so, she cannot swallow because of partial or complete paralysis of the throat and medicine should not be given by way of the mouth as some of it is apt to get into the lungs. Most cases of pneumonia, following milk fever, are caused by attempts to give medicine in this way. Where possible call a veterinarian.

Caked udder may be relieved by giving a laxative, massaging the affected parts and applying hot cloths. Stop feeding grain.

BEEF CATTLE.

Certain areas of the Upper Peninsula are well adapted to beef cattle raising. The census for 1920 gives the number of beef cattle in this section as 7,346, with a valuation of $321,437.00.

The abundance of pasture and cheap grazing lands favor beef production, especially on the large farms. During the past few years, there has been several large beef cattle holdings in the Upper Peninsula. Their stock has made good gains during the summer months. It is very necessary to provide winter feed and sheds. The failure to do this has caused heavy losses to many of the cattle men. Until this section becomes much more developed agriculturally, the production of feeders will be the main project. The feeds for finishing the cattle, however, can be produced as economically in this region as in any other part of the State, after sufficient areas have been put undr cultivation.

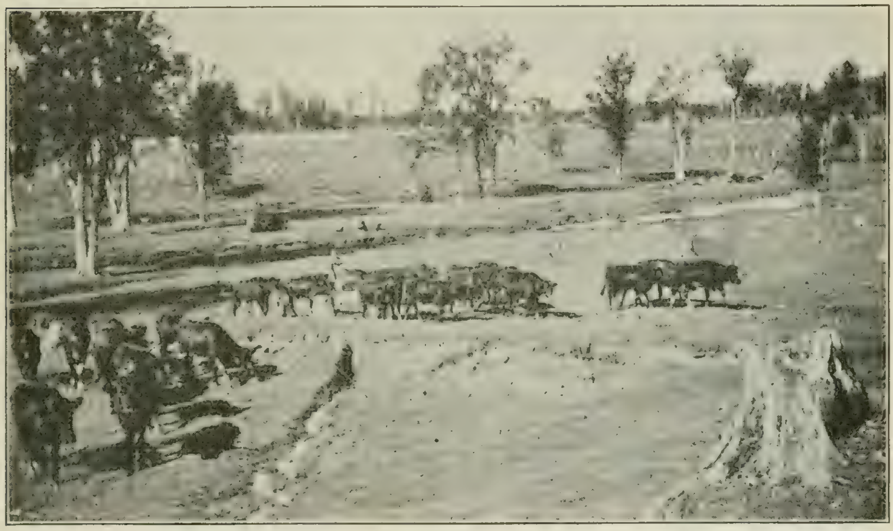

Fig. 30. A carload of feeder steers that gained 214 pounds in 107 days on pasture at the Upper Peninsula Experiment Station at Chatham.

The following figures are given as evidence of what can be done under general conditions:

On June 17, 1918, twenty-six steers weighing an average of 694 pounds, on arrival from Chicago, were turned on cut-over pasture at the Upper Peninsula Experiment Station. The following October they averaged 908 pounds, giving an average gain of 214 pounds per head, in 107 days.

John Brown at Kenton, purchased 35 yearling steers January 10th at Chicago. These steers were fed clover hay until spring, pastured in slashings until August 1st, then on second growth clover the balance of the season.

Average weight when purchased January 10, 700 lbs. in Chicago.
Average weight when sold December 10, 993 lbs. in Kenton.
Average gain for 11 months, 293 lbs.
Average gain per day, 7/8 lb.

The following table gives the results of breeding operations with high grade Herefords by Geo. M. Mashek, at Northland, in Marquette county. These cattle were carried through the winter in a rough shed and received no grain.

Year	No. head of cows	No. calves raised	Calves sold	Average age	Average weight in Chicago
1919	8	8	8	17 mo.	830
1920	19	19	19	17 mo.	899

SHEEP.

The census report for 1920 gives the numbers of sheep in the Upper Peninsula as 26,342 head, with a valuation of $370,046.00.

The possibilities for developing farm flocks of sheep in this section are very good. There are several areas well adapted to large sheep outfits. Several men have run large bands of sheep during the grazing season with excellent success, as far as gain in weight is concerned. Many of them failed because of the lack of preparation. The principal reasons for failure were: (1) running stock in unfenced pasture, (2) lack of sheds, (3) not raising their winter feeds.

The grazing season is long enough to develop a 70 to 80 pound lamb, even when the sheep are run in comparatively large numbers.

TABLE 29.—DATA REGARDING LAMBS SHIPPED OUT OF THE UPPER PENINSULA.

Owner		Average age when shipped	Average weight at receiving yard
J. Carson, Newberry, Luce Co., 1919	482 lambs	5½ mo.	76.1
Carley & Keene, Limestone, Alger Co., 1919	795 lambs	5 mo.	66.9
U. P. Experiment Station, 1919	73 lambs	6 mo.	78⅓
U. P. Experiment Station, 1920	89 lambs	6 mo.	78
U. P. Experiment Station, 1921	92 lambs	6 mo. 10 days.	82

The dressing percentages were secured on two shipments which are as follows:

J. Carson, lambs— 50 lambs, plain dressed..........49.40 per cent.
J. Carson, lambs—104 lambs, plain dressed..........51.80 per cent.
Carley & Keene, 795 lambs, plain dressed............50.10 per cent.

The average dressing percentages (as given by Armour & Co.) for grass-fed lambs, is 47 to 48 per cent and grain fed lambs 47 to 49 per cent.

The above mentioned lambs were all shipped to market direct from the pastures in the fall. The weights and dressing percentages show that lambs not only grow to maximum weights desired by the packers during the grazing season, but that a large percentage of them kill out well.

BREEDS ADAPTED.

The breeds of sheep best adapted to the Upper Peninsula are those having close fleeces, including medium and fine wools, such as the Hampshire, Shropshire, Oxford, Southdown and Rambouillets.

The coarse wooled breeds do not do their best in this climate as their fleeces are too open. The Southdown lambs do not attain the heavy weight that lambs of other Down breeds do, during the grazing season, and they also shear light. The Rambouillets shear heavier than the other breeds mentioned and their wool usually commands a higher price. They are especially well adapted for the larger flocks.

The small farm flocks usually pay best when they carry largely the Hampshire, the Shropshire or Oxford breeding. Some of the advantages in favor of sheep raising in the Upper Peninsula are: they assist in land clearing; they require the minimum amount of labor; they make good use of rough feeds; they require only cheaply constructed shelter; and they give a crop of wool in the spring, a crop of lambs in the fall and are naturally well adapted to this northern country.

Fig. 31. Sheep are an effective means of aiding in land clearing work. Twenty sheep are equal to the labor of one man in brushing and clearing up the second growth on cut-over lands being prepared for breaking.

SUMMER AND FALL CARE.

Sheep do better on short and fine grasses than on coarse or overgrown feed. They relish a great variety of weeds and brush and are of great value in cleaning fields after harvesting and in killing low brush and weeds in cut-over lands. New farm settlers will find it a good practice with at least a part of their clearing operations on cut-over lands, to first cut and burn the larger brush, sow grass seed, then use the land for pasture for two or three years, while the roots are rotting. The sheep not only keep the green growth down, but bring in a profit to their owner.

Sheep need free access to salt all the time, and they must be kept away from bog-holes, containing stagnant water during warm weather. A change of pasture occasionally is very beneficial. Sheep will do much better on a certain area of pasture if it is divided into two or three parts, and the sheep changed every two weeks.

No grain is necessary during the pasture season. The native grasses alone will carry a ewe with her lamb through the season so that both can go to the market, fat, in the fall, even when run in comparatively large bands. This has been demonstrated on several large sheep farms in Delta, Dickinson, Iron and Marquette counties, during the past few years.

Where convenient, a pasture near the sheds should be left for late fall and early spring grazing, as it will shorten the winter feeding considerably, and gives the ewes the exercise they need.

A vigorous, matured ram will breed 40 to 60 ewes. When used to that extent, he must be in good condition and be removed from the flock at night, fed grain, preferably oats/and bran, and hay. Feed again in the morning before turning him in with the ewes.

Great care should be taken at breeding time to see that every ewe is bred. The ewes should be tagged before turning the rams in with the flock. The period of gestation in sheep is 145 days. It is not advisable to breed ewe lambs.

WINTER MANAGEMENT.

Early lambing requires better housing conditions, more and better feed and considerably more labor than when lambs come after warmer weather and grass starts. A greater loss of lambs and a lighter fleece must be expected with early lambing. When the additional price received for the lambs is sufficient to off-set the added cost of production, then early lambing is advisable. The majority of farmers favor wintering their ewes as economically as possible, lambing about the time grass starts.

Clover hay, alfalfa and silage are the best feeds for sheep. When clover and alfalfa hay are high priced, other roughages such as oat and wheat straw, corn fodder, pea and oat hay, and pea straw can be used to good advantage. Barley and rye straw are objectionable because of the beards. Rye straw often contains ergot, which causes abortion in the ewes. Matured sheep require from three to three and one-half pounds of hay per day, when no other feeds are provided. When a

Fig. 32. There is a place for a few sheep on most every farm.

poorer quality of roughages, such as straw and corn stalks are used, a little grain should be given. One-half pound of oats, or oats and bran, the latter in proportions of two parts of oats to one of bran makes a good grain ration. A succulent feed is necessary for the most economical wintering of sheep. Root crops, such as rutabagas, turnips, carrots or silage can be used. Two pounds of either root crops or silage per head per day gives good results. Mouldy feed of any kind is objectionable. Grain and water troughs should be kept clean.

CARE OF EWES AT LAMBING TIME.

As lambing time approaches, give the ewes a little additional feed and trim the wool around the udders. They will need attention both day and night to see that the lambs do not get chilled before they are dry; that the mothers have milk for their lambs and that they will own them. If a lamb is chilled even to the point where it is stiff, it can usually be revived by putting it into warm water until the circulation is restored, wrapping it in a dry blanket until it is dry, giving a feed of milk, then returning it to its mother. After a lamb is dry and has a feed of its mother's milk, it will stand a lot of cold. The best success is obtained by placing ewes about to lamb into four feet square lambing pens until the lambs are from two to three days old.

DOCKING AND CASTRATING LAMBS.

All lambs should be docked, (tails removed) regardless of whether they are to be kept as breeders or marketed. Docked lambs look trimmer, are cleaner and are in less danger of being infected with maggots during the hot sultry weather. The best time to dock lambs, is when they are from ten days to two weeks old. At that age, they bleed but little and there is little shock to the lamb. A sharp knife or docking iron is used and the tail cut about one inch from the junction with the body. Apply a disinfectant after the operation, also a little pine tar if the flies are bad.

All male lambs not intended for breeding purposes can well be castrated at the same time they are docked. Ram lambs, after they are four months old, do not grow as rapidly as wether lambs and do not fill out as well, consequently they command a lower price on the market. The following tables gives the prices received from sale of ram lambs, vs. wether lambs, from the Chatham Experiment Station. The ram lambs were pure breds that were not true to type, for the breed:

TABLE 30—DATA SHOWING LOSS IN SALE PRICE OCCASIONED BY FAILURE TO CASTRATE LAMBS.

	1919 Price, per cwt.	1920 Price, per cwt.	1921 Price, per cwt.
Ram lambs	$10.00	$10.00	$5.50
Wether lamb	15.50	12.85	8.25

Feeding racks should be constructed so that no chaff or feed can fall on the sheep's fleece. The value of the fleece is often reduced one-half by carelessness in this respect. Crowding through narrow doors frequently causes the loss of lambs, all openings should be large enough to avoid crowding.

HOUSING.

Sheep do not need an expensive barn. Any shed that will keep them dry and keep out the wind is sufficient. They soon lose vitality when housed in a warm, unventilated barn.

HEALTH.

Sheep that are pastured on well drained land, well fed and wintered in well ventilated sheds are usually in good health, unless afflicted with parasites.

There are two classes of parasites, the external and internal. The external parasites, lice, ticks and maggots can be controlled by dipping. Dipping is usually done shortly after shearing, as it takes less dip and the weather is usually warm. Maggots often do considerable damage during hot, wet weather. Apply gasoline or diluted turpentine to kill them. Then add a disinfectant with a little pine tar to prevent infection and to repel flies. The internal parasites most liable to be troublesome, are stomach and lung worms.

Owing to the cool climate of the Upper Peninsula, stomach worms do not have the opportunity to multiply that they do in the warmer areas. Sheep that have been pastured continuously on one field, often are effected, also those that have had rams introduced from infected flocks. Directions for treatment may be secured by writing this Experiment Station.

Fig. 33. A bunch of pigs in the feedlot on the farm of John Mann, Houghton County.

Sheep pasturing on low lands and drinking from stagnant pools, often develop lung worms. Lung worms are light colored, thread-like worms that feed on the lining of the tubes to the lungs. As they increase in numbers, they lie in clusters in the tubes, shutting off the circulation of air.

No successful practical treatment has been found. The best method is to send to market all weak sheep and those with a hacking cough and keep the balance of the flock on well-drained pasture where there is no stagnant water.

HOGS.

The census report for 1920 gives the number of hogs in the Upper Peninsula as 22,502, with a total valuation of $448,551.00.

Both the lard type and the bacon type hogs are well adapted to this section. The best system in most sections of the Upper Peninsula is to produce one litter per year and that in the spring. The most satisfactory way is to run the pigs on pasture with a little grain during the summer months and finish them on full feed of grain. Barley and field peas are excellent finishing feeds for use after the pasture season is over. On farms that have good housing conditions for the pigs, and that raise plenty of grain for feed and have plenty of skim milk, the fall litters can be developed successfully. On every farm where either clover pasture or skim milk is available, a few pigs will help increase the family income.

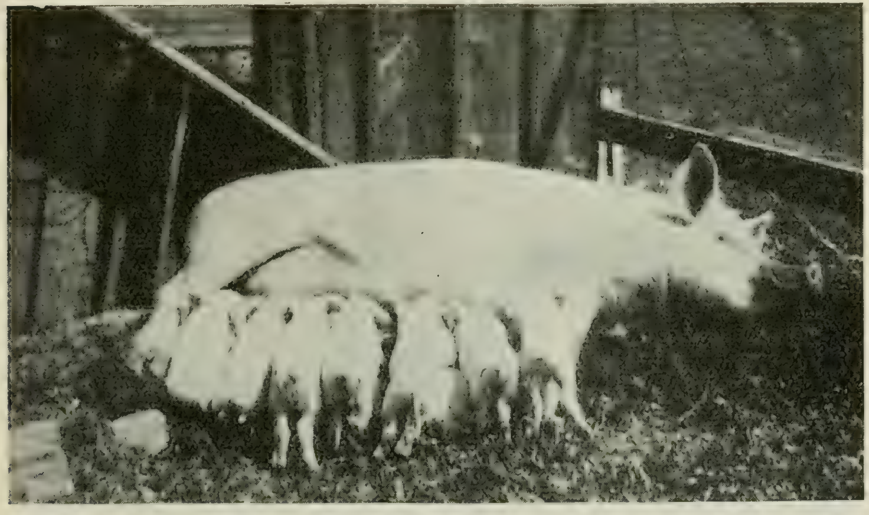

Fig. 34. A promising group of Yorkshire pigs on a farm near Stephenson, Menominee County.

HORSES.

There were 25,069 horses in the Upper Peninsula in 1920, valued at $3,915,404.00, according to the census report. These are principally of two types: the light draft, weighing from 1,350 to 1,500 pounds and the heavy draft, weighing over 1,500 pounds. The heavy draft horses are largely shipped in from the corn belt states and used in the woods, cities and towns. Many of the light draft horses are raised in this territory. Chippewa and Menominee counties are the leading breeding sections.

POULTRY.

The 1920 census reports 243,885 chickens raised in the Upper Peninsula.

No farm is complete without a flock of poultry. The size of the flock will depend on the amount of land under cultivation, distance from market and the importance placed on poultry receipts in the general farm plan.

There are locations in the Upper Peninsula where specialized poultry farms can be made a success, but usually the greatest profit per fowl will be made by the medium-sized farm flock. The reasons for this greater profit is that the farm flocks have a wider range, consequently gather the greater part of their food during the summer months, and they are generally taken care of by the women and the children.

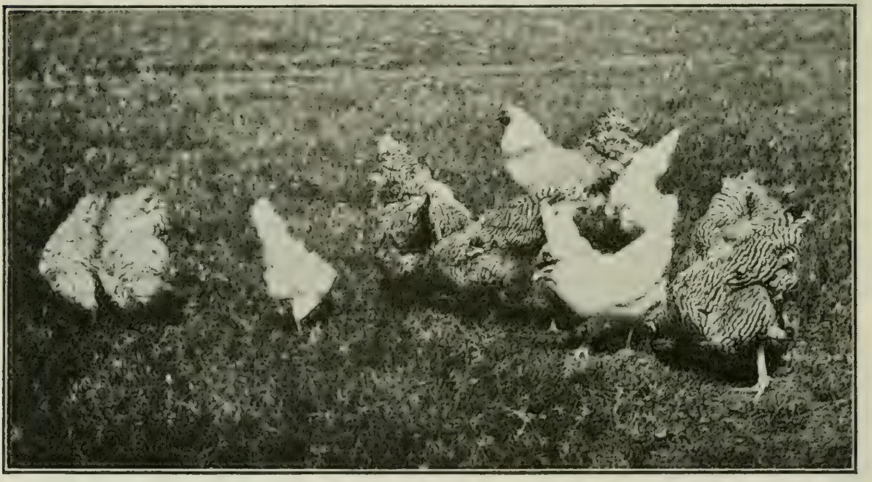

Fig. 35. The barred rock hens in the picture have a production record of 217 eggs per year at the Chatham Station.

FLOCK MANAGEMENT.

Free range, plenty of fresh water and skim milk, a light feed of grain in the morning, a heavier feed at night, with dry mash always available, with a clean coop free from lice, will bring good results with any good laying strain of hens. During the summer the poultry will gather a good deal of their feed, but for high production this feed should be supplemented by the scratch feed and dry mash. Lice increase rapidly during the warm weather, especially when the poultry house is not sprayed or white-washed occasionally.

Good judgment and careful attention are necessary to get good results from poultry during the winter season. To get best results, early summer conditions should be duplicated as nearly as possible. At that time the birds get plenty of exercise, fresh air, green food, meat (bugs, worms, flies), grit and the grain that is fed them. During the winter months, the exercise can be provided by mixing the grain in a deep litter of clean straw and chaff; the green food by feeding cabbages, roots, sprouted oats, clover and alfalfa. Grit, oyster shell, green food and skim milk should be supplied. Both the dry mash and the scratch grain should be used to get best success.

The following rations are advocated for the Upper Peninsula by the Poultry Department of the College.

Scratch Feed.	Dry Mash.
2 parts cracked corn	20 per cent corn meal
1 part wheat	20 per cent ground oats
1 part heavy oats	20 per cent bran
	20 per cent middlings
	20 per cent beef scraps

Cull the flock before starting winter feeding. Full instructions on culling can be received through the County Agent or the Poultry Department of the Michigan Agricultural College at East Lansing. Blue prints for poultry houses that are especially adapted to the Upper Peninsula can also be secured from the above sources.

LIVESTOCK IMPROVEMENT.

The agricultural future of the Upper Peninsula is going to depend largely on the interest developed in the improvement of livestock. Considerable progress is now being made along this line. Scrub stock cannot compete successfully with the high grade of pure bred stock. Improvement of livestock can be accomplished through better pure-bred sires, co-operative bull associations, cow-testing associations, culling the herds and flocks and by stimulating boys' and girls' club work in the different communities.

BULL ASSOCIATIONS.

The sire is half the herd as far as the influence on the progeny is concerned, consequently, improvement in the herd can be best accomplished by using better sires.

Where a farmer has not a large enough herd to pay him to keep a high-class pure bred bull, he should join with a few of his neighbors and organize a bull association. In that way they can own a better sire than anyone of them could afford to buy.

Banish the scrub bull from the roadside.

The scrub bull is a menace to livestock improvement in any community, but doubly so in newly settled areas, where many cattle run at large. There is a law on the statute books prohibiting owners from letting bulls run loose on the roads, nevertheless it has but little effect until public sentiment within the communities has been developed sufficiently so that it is more popular for the officers to enforce the law

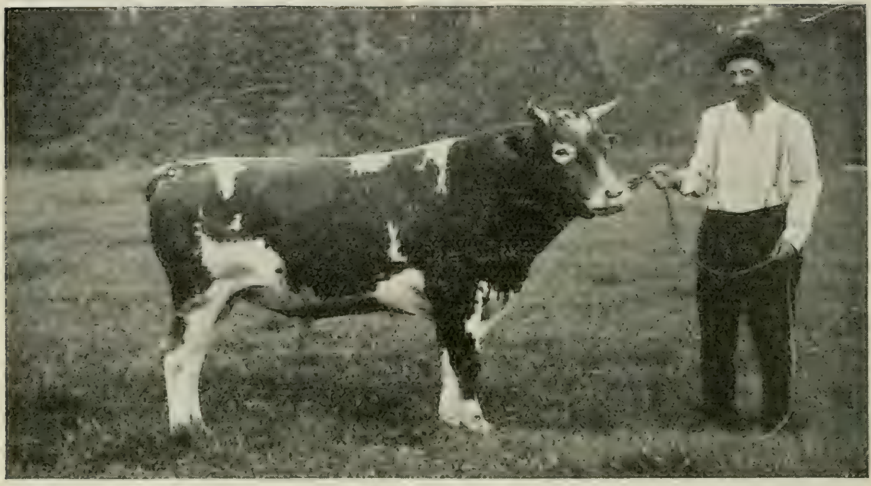

Fig. 36. Guernsey bull Larry Pendent, 19054, owned by the Stanley Breeders' Association, which consists of twenty farmers (Iron County). There are a number of such associations in the peninsula.

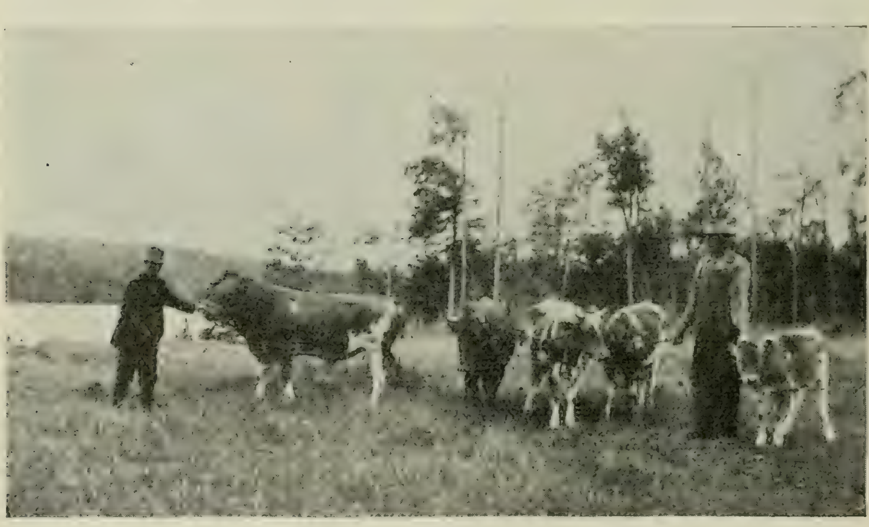

Fig. 37. A picture showing very plainly the advantage of using a pure-bred sire. The old red cow bred to a pure-bred Guernsey bull produced the grade cow standing next to her. The two heifers on the right are daughters of the above grade Guernsey cow and the pure-bred Guernsey bull. Stanley Guernsey Breeders' Association, Iron County.

than to be indifferent to it. There is but little incentive for a farmer to keep a pure-bred bull as long as there is constant danger of his cows being bred by stray scrub bulls.

COW TESTING ASSOCIATIONS.

The cow-testing associations are proving of great assistance to dairymen in building up their herds. The milk scales and Babcock tester should be more generally used in culling out the boarders. There are still many herds containing cows that do not pay for their feed.

BOYS' AND GIRLS' CLUB WORK AN IMPORTANT FACTOR IN IMPROVING LIVESTOCK.

In 1921 there were 17 boys' and girls' livestock clubs in the Upper Peninsula, with an enrollment of 178 members, owning a total of 227 animals. There were also 10 poultry clubs with a membership of 73, owning 1,520 birds. These 300 boys and girls owning either high-grade or pure-bred stock, are a great help toward establishing better livestock in their respective communities.

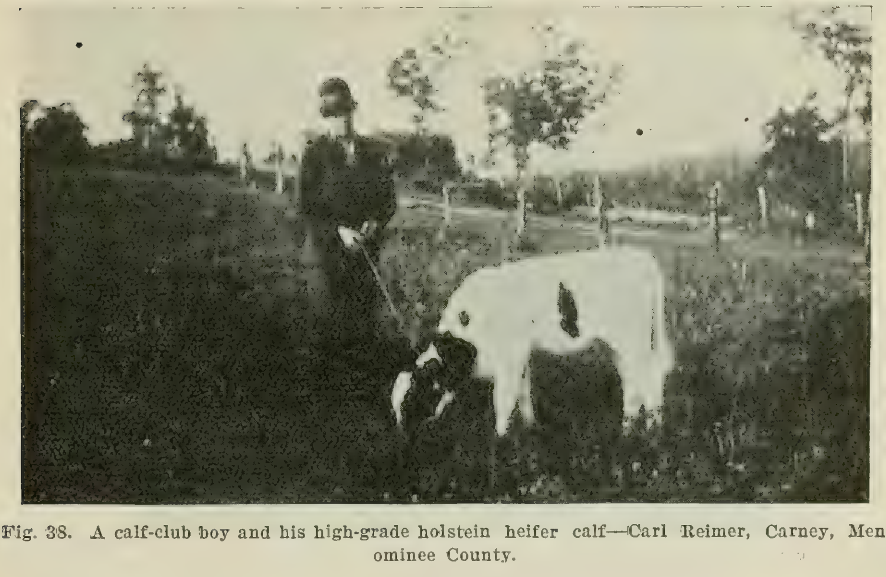

Fig. 38. A calf-club boy and his high-grade holstein heifer calf—Carl Reimer, Carney, Menominee County.

BEES*.

Beekeeping in the Upper Peninsula is as yet in its infancy. The splendid crops of fine honey obtained, however, by those commercial beekeepers who are now operating apiaries in the Upper Peninsula demonstrate that there are wonderful possibilities for the development of the industry, especially in those districts having clay or heavy loam soils. On these soils the alsike, white and sweet clovers, fire-weed, raspberry and golden-rod grow in abundance and under favorable weather conditions, provide heavy yields of nectar. As the climatic conditions are very favorable for the development of these nectar-bearing plants during the summer and early fall, and as the honey from these sources is of the very best, it is evident that beekeeping is sure to prosper.

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*By Russell H. Kelty, Entomological Section.

The census report for 1920 shows that there are nearly five hundred colonies of bees already in the Upper Peninsula, a relatively small number of which are in the hands of commercial beekeepers. The absence of bee-diseases, together with the favorable conditions for honey production, assure the success of commercial beekeeping in the Upper Peninsula.

Fruit Growing in the Upper Peninshla.

The kinds of fruit grown are limited by the length of the growing season, the distribution of rainfall, and the variation in the range of temperature of the days and nights.

By referring to the discussion on climate, the areas will be found which are influenced by the great lakes, where the variation between night and day temperature ranges 18 degrees or less, and where this body of water tempers the winter as well as the summer temperature. Those areas lying on favored locations in relation to the great bodies of water are further protected by the "land and lake breezes" which are common throughout the Great Lakes area and which consist of land breezes during the day until mid-afternoon when a strong breeze from the lake sets in causing a fall in temperature but which protects the section so favored from extremes of temperature and mid-season frosts. Such areas for fruit should be located so that good air drainage can be secured. In general the climate is such as to favor the growing of the summer and fall varieties of apples, sour cherries, Japanese plums, and practically all small fruits such as currants, gooseberries, raspberries, strawberries, etc.

Fig. 39. Fruit growing in the Upper Peninsula is in its infancy. Many sections have conditions favorable to both tree fruits and small fruits.

The soils available for fruit growing are rather well distributed. The soils that are capable of producing farm crops generally, will produce fruit providing the location is right.

Apples generally do well on the clay loams and sandy loam soils. Cherries and plums do best on the sandy loams and sandy soils. Strawberries are being grown on all classes of soils from the heavy clays to the lighter sands. (The Jack pine soils are not included in this classification of sand soils.)

Fruit growing in the Upper Peninsula is just beginning to develop. The growers giving proper attention to the selection of a location, proper fertilization and care, selection of proper varieties and who are spraying for insects and diseases common to fruit in this section are producing good crops of fruit of fine quality. The varieties found to be successfully grown over the Upper Peninsula generally are:

Apples: Summer varieties—Yellow Transparent and Duchess.
Fall varieties—Wealthy, McIntosh, Fameuse (Snow), (Northwestern Greening, Alexander and Wolf River, hardy but poor quality).
Crab Apples: Hyslop and Transcendent.
Plums: Burbank, Lombards, Bradshaw.
Cherries: Montmorency, Early Richmond.
Currants: London Market, Perfection, Wilder.
Gooseberries: Downing.
Raspberries: Cuthbert, King.
Blackberries: Eldorado.
Strawberries: Senator Dunlap, Gibson, Aroma, Champion (Everbearing).

TRUCK CROPS.

In commercial truck growing three factors are of prime importance: (1) location with respect to market, (2) adaptation to climatic conditions, (3) adaptation to soil types.

Location: Many of our truck crops, such as canning peas, cucumbers, etc., are dependent on a market close to home. That is, these crops are produced for a canning factory or pickling plant in a well-defined area surrounding such a factory. Celery, onions, head lettuce and other truck crops of this nature can be produced without special regard to location of the market, yet they must have a dependable market and dependable transportation facilities in getting to that market.

Climate: The climate of the Upper Peninsula is very well suited to the production of many of our important truck crops. This is especially true of certain areas adjacent to the Great Lakes. The Garden Peninsula in Delta county is probably one of the finest locations with respect to climatic adaptations to truck crops.

Soil Types: With the wide range in soil types found in the Upper Peninsula it is possible to locate suitable soils for truck growing in most any section of the territory. The truck areas are usually located with reference to market conditions and not to soil types. The celery gardens at Newberry are an exception; they are located with reference to soil type and transportation facilities to market. The canning peas,

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Information on pruning, spraying, planting, fertilization, etc., can be obtained in detail from the Horticultural Dept., Michigan Agricultural College, East Lansing, Michigan.

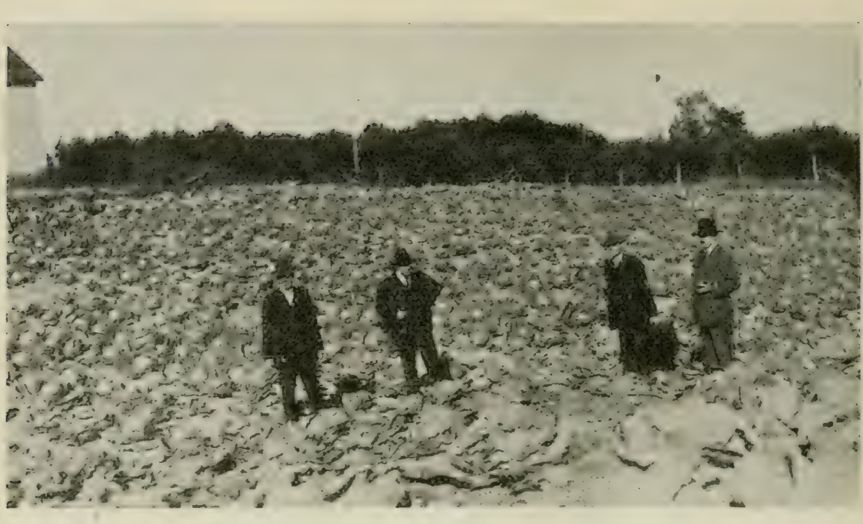

Fig. 40. Special crops such as celery, cucumbers, peas, cabbage, etc., have a place in the agricultural development of this region. Cabbage on the field of Robert Blemheuber, Marquette.

sweet corn, and cucumber crops are being produced in Menominee county because there is a local market at the canning factory, in addition to the favorable climate and suitable soil conditions. The possibilities of canning factories in the section are very good, because in addition to truck crops there is an abundant supply of native small fruits such as raspberries and huckleberries.

Further information on the culture of truck crops can be obtained direct from the Horticultural Department, East Lansing, Michigan.

FOREWORD.

Milk is a most highly decomposable food. Ranking as it does at the top of the list of foods from the standpoint of completeness, availability and general acceptability, it tends to occupy the position at the foot of the list from the standpoint of keeping qualities. It is, therefore, very essential that careful study be made not only to devise methods for improving the quality and prolonging the keeping quality of milk, but also to devise tests whereby the quality and the keeping quality may be easily and accurately estimated. Quite naturally the earliest efforts to determine these points scientifically consisted in using the common bacteriological technique of estimating numbers of bacteria by plating. More recent technique has been developed whereby the number of bacteria may be estimated by direct microscopic examination of the milk. Methods are available whereby the amount of dirt in milk may be made visible and estimated. Other tests have resulted from approaching the problem from a different angle, one in particular being based upon the determination of the activity of certain enzymes in the milk. Cooledge and Wyant of this Station have already announced the discovery of a method intended to determine the activity of both bacteria and the enzymes in the milk. This method appears to be both simple and accurate, particularly when the apparatus designed by the former is employed to make the readings. The present bulletin describes the technique employed and the apparatus devised and a comparison of several of the methods that are at present advocated for testing the keeping qualities of milk. There is also included a plan for grading milk and paying a bonus based on the keeping quality as determined by this method. The method described and employed proves to check far more closely with the actual keeping qualities of the milk than do the other methods with which it is compared.

The author acknowledges his indebtedness to G. G. Speeker and L. C. Emmons of the Mathematics Department for their assistance in furnishing a mathematical interpretation of Table 7.

WARD GILTNER.

THE COLORIMETRIC HYDROGEN-ION DETERMINATION AS A MEANS OF STUDYING BIOLOGICAL CHANGES IN DAIRY PRODUCTS.

Technical Bulletin No. 52

BY L. H. COOLEDGE

The method usually applied in a study of the sanitary condition of dairy products is the bacteriological count. This is determined by the plating method, which gives an approximation of the number of individuals or groups of live bacteria present in the sample, or by the microscopic method which gives an approximation of the total number of bacteria, both dead and living which are present. Either of these methods is a valuable aid to the sanitarian in judging the care which has been exercised in producing the milk, and the precautions observed to prevent the growth of any bacteria present.

The bacteriological count fails to indicate with a sufficient degree of accuracy the actual ability of the bacteria present to produce the changes which would make the dairy product unfit for consumption, and it is often the case that the sample of milk with so high a bacterial count that it would be condemned by most of our city ordinances, is actually a good grade of milk when judged as to keeping quality and type of fermentation which develops when held at the temperature commonly used in the home.

To find a method which would give a reading more nearly representing the actual ability of the bacteria and enzymes present to produce the changes of interest to the producer and consumer, Cooledge and Wyant (1) made a study of the ability of bacteria and enzymes present in milk to cause a change in hydrogen ion concentration of a broth solution to which the milk was added. The object of this paper is to call attention to the possibilities of this method when applied not only to market milk but to other dairy products, and in other phases of bacteriological investigation and to serve as an introduction to work which is under way upon each of the subjects considered.

REVIEW OF LITERATURE

The work of Clark and Lubs (2) and of a number of other investigators shows that the hydrogen ion determination furnishes a delicate means for measuring certain biological changes in solutions and that the same may be determined with a fair degree of accuracy by colorimetric methods.

Baker and VanSlyke (3) have devised a method for determining the keeping quality of milk in which the indicator Brom-cresol-purple, is added to the whole milk to be tested, and the color noted after 24 hours at room temperature. Four stages of progress are thus noted depending upon the color of the milk indicator solution. The objection to this method is the length of time required to get results. It is probable that the samples held could be more accurately classified after 24 hours by simply tasting. The opacity of the milk makes the detection of slight changes in color difficult.

Cooledge and Wyant (1) obtain results which check well with the actual condition of the milk by adding 0.1 cubic centimeter of the milk to be tested to a tube of broth containing the indicator Brom-thymol blue and incubating at 37°C. pH readings are made hourly and the condition of the milk is judged by the rate of change. Results are thus obtained in from 1 to 8 hours which enable the writers to divide the milk into 17 classes depending upon the ability of the bacteria and enzymes present to cause the changes in readings.

METHODS

Preparation of Media. The only medium necessary for this work is the bouillon cube broth recommended by Wyant (4) and containing the indicator Di-bromthymol sulphonephthalein (Brom-thymol blue). One bouillon cube, 1 percent Witte's or other peptone, 0.5 percent salt are added to each liter of water and after the usual heating and filtering 80 cc. of a 0.04 of 1 percent aqueous solution of brom-thymol blue added for each liter of broth. The broth is then cooled to 20°C. and the color adjusted to compare with tube 6.8 of the standards which are mentioned later. A compensating blank, broth without indicator, must be placed in front of the standard and the readings must be made at room temperature.

The broth is then placed in 100 or 200 cc. flasks sterilized, and stored. When needed 10 cc. of the broth indicator solution is transferred to a 2.8 x16 cm. sterile test tube with a 10 cc. sterile pipette and compared with standard tube pH 7.0 in the comparator. A few drops of N/1 NaOH or HCl are then added to the flask of indicator solution if needed to make the color of the broth solution compare with tube pH 7.0. Broth without indicator must be used as a compensating blank in front of the standard tube. The broth is now ready to use and is transferred in 10 cc. portions to 2.8x16 cm. sterile test tubes using a sterile 10 cc. pipette.

Preparation of Samples. In taking samples the same precautions should be observed as when sampling for other bacteriological tests. Preliminary experiments, however, indicate that pipettes may be re-used with safety after rinsing in hot water.

It is desired to add 0.1 cc. of milk to each tube of brom-thymol blue broth. To reduce the error due to measuring direct as small an amount of milk as 0.1 cc., sterile 9 cc. water blanks in test tubes are prepared and 1 cc. of the milk to be tested added to these. After thorough mixing 1 cc. of each diluted sample is transferred to a tube of the broth.

Incubation. After the 0.1 cc. portions of milk have been added to the tubes containing brom-thymol blue broth they are placed in a water bath or incubator at a temperature of 37°C. Hourly observations are made to detect the first change in color of the indicator due to the development of acidity resulting from the activity of the bacteria and enzymes present. As soon as pronounced changes are noticed, hourly readings are made by placing the tubes containing milk—broth—indicator in the comparator and comparing with the standard tubes as mentioned below. The samples must be placed in a water bath and cooled to 20°C. before readings are made. In this work readings should be made at a constant temperature. The readings of the unknown and standards vary somewhat with change in temperature, making this precaution necessary.

Standards. The standards are the buffer solutions described by Clark and Lubs (2). Ten cc. portions are placed in the 2.8x16 cm. test tubes with the same amount of indicator that was placed in each 10 cc. of the broth solution and sealed. In this way the standards will keep for a considerable period. The standards with the following readings are used in this work, pH 7.4, 7.2, 7.0, 6.8, 6.6, 6.4, 6.2, 6.0, and 5.8. These standards may be prepared in any chemical laboratory, or if one has not the facilities for making may be obtained from Hynson, Wescott and Dunning of Baltimore at a reasonable price.

Comparators. Colorimetric procedures in experimental and analytical chemistry have grown in favor during the past few years until at the present time many determinations are quickly made by colorimetric methods which required tedious gravimetric technique a few years ago.

To meet this growing demand several types of comparators and colorimeters have been devised during the past few years. Most of these are not suitable for the determination of pH where the standards are in test tubes and need not be considered in connection with this work.

In using the technique of the colorimetric hydrogen ion determination to read the approximate pH of solutions in test tubes the writer found the method of changing standards and unknowns in the comparator so tedious and time consuming that the desired number of readings could not be made each hour. With the idea of finding a more convenient comparator or of devising a means which would make the reading of a greater number of determinations possible, a study was made of the types in which unknowns in test tubes were compared with standards in test tubes. As none of the comparators in use were found to meet the requirements of this work the following arrangement, a modification of the comparator of Hurwitz, Myer and Ostenberg was designed. (Fig. 1).

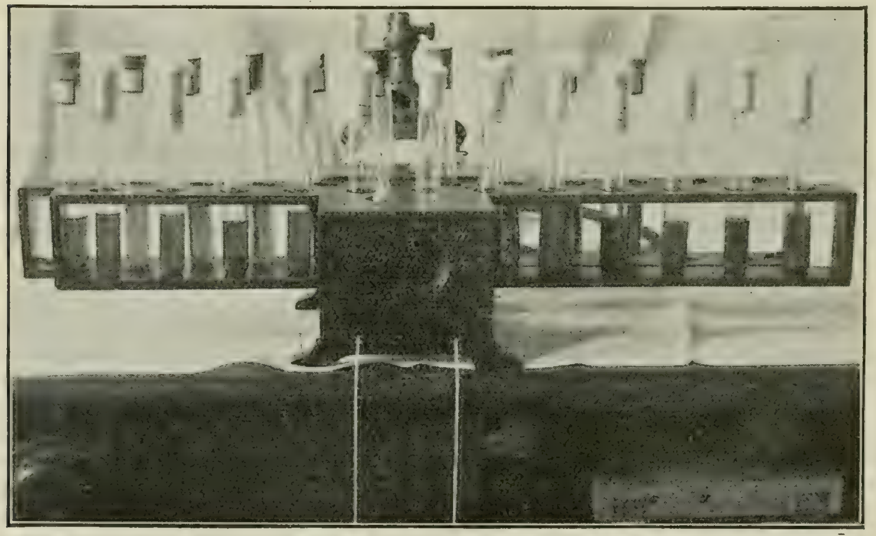

Fig. No. 1 A comparator designed for examining a large number of samples in a short time.

Two sliding test tube racks are constructed and so arranged in the comparator that the one carrying the standard tubes B (Fig. 2) can be slid back and forth until a tube is found that compares in color with the first unknown in the second rack A. The rack containing standards is moved back and forth by pulling the strings shown in the cut. The second rack A carrying the unknowns is then moved along one place and the reading of the second unknown found in the same way. The under surface of each sliding rack is indented opposite each test tube, the indentation being designed to receive a cog supplied with a spring. By means of this arrangement the tubes are stopped with a click at the proper place in the path of light as the racks are moved back and forth. Rack B is so constructed that it can be removed readily and replaced by other racks containing standard tubes for other ranges of pH.

The readings are made by using light directly transmitted or the comparator is tilted by placing books under the end toward the observer and light reflected from a white surface through the tubes.

It is possible by using this comparator to examine, in a given time many times the number of samples which could be examined by the old method. This comparator is now being placed upon the market by the Central Scientific Company of Chicago.

The comparator described above is indispensable to the worker wishing to examine a number of samples of milk at a time. For one who examines only a few samples, the combined comparator and storage rack, designed by Cooledge and Klever will be sufficient. (Fig. 3).

Two strips of wood 1¼ inches by 3 inches by 14 inches are selected and thirteen ¾ inch holes sunk in one edge of each. One of these is used as the

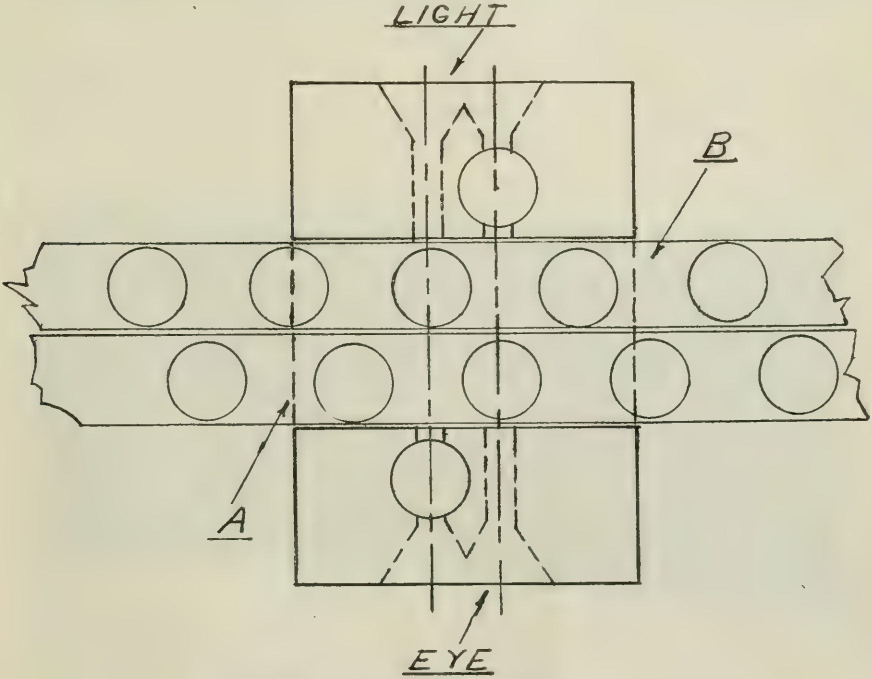

Fig. No. 2. Detail of comparator shown in Figure No. 1.

base and the other as the cover. Slits are cut through the sides to the middle three holes of the base and of the cover. Two sets of steel clamps are made and grooves cut into the wood in such a manner that one set can be used to clamp the cover on when the standards are not in use and the other set to clamp the inverted cover beside the base when the combination is to be used as a comparator.

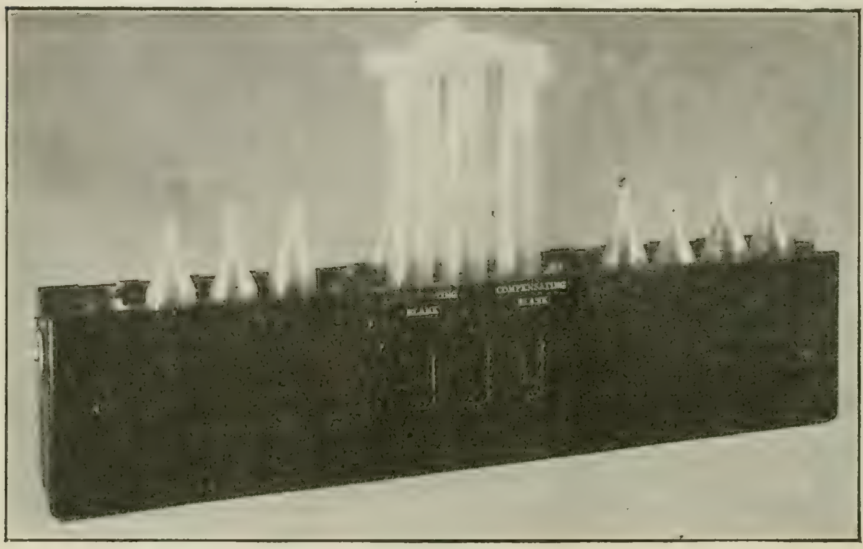

Fig. No. 3. A combined comparator and storage rack for standards.

The advantage of this simple rack and comparator is that it furnishes a convenient place for storage of standards away from dust, light and danger of breakage and makes an excellent shipping package. (Fig. 4). Where

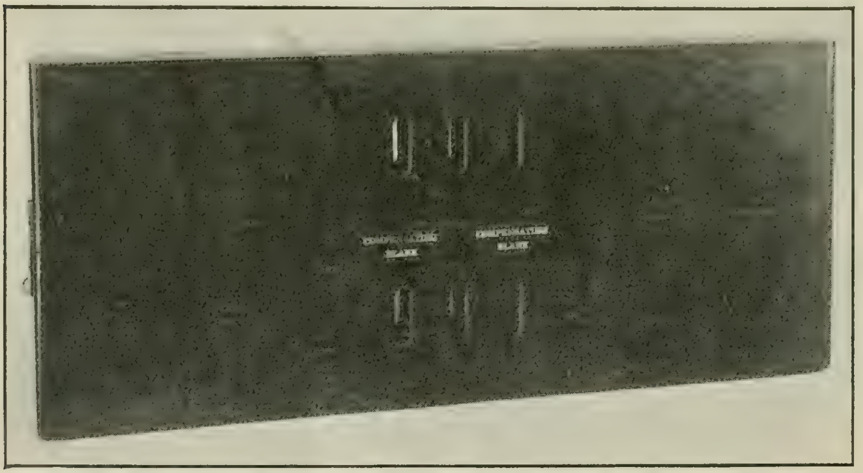

Fig. No. 4. This comparator and rack for standards is furnished with the sets of standards put on the market by Hynson, Wescott and Dunning.

used as a comparator the convenience of having the standards at hand is valuable. The three middle holes may be used for storing compensating blanks. An extra hole at the end holds the comparator clamps when the cover is adjusted.

EXPERIMENTAL WORK

The experimental work which has been completed for this paper is intended to show briefly the application of the colorimetric hydrogen ion determination to the subjects considered. Studies which are under way and projected will take up in detail the various phases of the work.

MILK PLANT SUPPLY

A method which could be used to judge the keeping quality of milk as it is delivered to the city milk plant, creamery, ice cream plant, and condensery has long been needed. Methods which are in use at the present time are faulty in that they do not give a true index of the keeping quality of the milk, are subject to considerable error, require a trained technician, are expensive of material and labor, and require too long a time before results are available.

The results tabulated in Table I are designed to show how the score of milks tested by the pH method compares with the bacterial count and with the actual keeping quality as judged by tasting after the milk had been stored for 24 hours at 21°C. The samples are scored as to pH change as shown in Table III taken from a previous paper.

A summary of the results in Table I rearranged in Table II shows that the average bacterial count checks up quite closely with the score based upon rate of change in pH. As shown in Table I there are many individual cases in which a high bacterial count does not indicate a sample of milk with poor keeping quality, nor does a low bacterial count always indicate good keeping quality.

In Table I it will be seen that samples with counts of 100,000, 120,000, and 185,000 bacteria per cubic centimeter were sweet at the end of 24 hours at room temperature while samples with counts of 11,000, 30,000 and 36,000 were sour or curdled. This was undoubtedly due to the fact that the first three samples were contaminated largely with inert or slow acting bacteria while the last three samples contained very active varieties which quickly soured the milk. In the actual practice of grading milk by the bacterial count alone the first three samples might have been condemned while the last three samples with low counts and poor keeping quality would have passed as a very good grade of milk. In this way an injustice is often done when milk is graded upon the bacterial count alone.

Table I

Comparison of pH Change in Milk, Bacteriological Condition, and Keeping Quality.

Number.	pH						Bacteria per cubic centimeter.	Acid bacteria per cc.	Gelatin liquifying bacteria per cc.	Milk 24 hrs. at room temperature.
	4 hours.	5 hours.	6 hours.	7 hours.	8 hours.	Score.				
X-3-9	.....	.....	.....	6.7	6.7	100	5,000	3,000	1,000	Sweet
X-131	.....	6.8	6.7	6.7	6.7	100	5,000	1,200	600	Sweet
X-130	6.8	6.7	6.7	6.7	6.7	100	6,000	2,400	2,000	Sweet
X-20	.....	.....	6.7	6.7	6.7	100	5,000	1,000	....	Sweet
X-21	6.8	6.7	6.7	6.7	6.7	100	35,000	4,900	....	Sweet
E-43-17	.....	.....	.....	6.7	6.6	95	14,000	7,900	2,100	Sweet
18	.....	6.8	6.7	6.6	6.6	95	50,000	10,000	7,000	Sweet
X-3-2	.....	.....	.....	6.7	6.6	95	2,000	1,000	1,000	Sweet
24	.....	6.8	6.7	6.7	6.6	95	30,000	10,000	1,500	Sweet
11	.....	6.8	6.6	6.7	6.6	95	17,000	2,000	300	Sweet
E-43-19	.....	.....	.....	6.6	6.5	90	6,000	3,000	3,000	Sweet
14	.....	6.8	6.6	6.5	6.5	90	100,000	30,000	....	Sweet
32	.....	6.7	6.7	6.7	6.5	90	25,000	3,500	4,000	Sweet
19	.....	6.8	6.6	6.6	6.5	90	60,000	4,800	4,800	Sweet
E-11-1	.....	.....	.....	.....	6.5	90	29,000	....	....	Sweet
E-43-16	.....	.....	.....	6.5	6.4	85	18,000	....	....	Sweet
130	.....	.....	6.6	6.5	6.4	85	25,000	10,000	2,000	Slightly sour
23	.....	6.7	6.6	6.5	6.4	85	120,000	30,000	....	Sweet
114	.....	.....	6.7	6.7	6.4	85	100,000	20,000	5,000	Sweet
121	.....	.....	6.7	6.6	6.4	85	130,000	15,600	97,000	Sweet
X-3-3	.....	.....	.....	6.4	6.2	75	25,000	10,000	12,500	Sweet
E-43-20	.....	.....	.....	6.3	6.2	75	185,000	100,000	....	Sweet
128	.....	.....	6.6	6.3	6.2	75	30,000	7,800	....	Slightly sour
122	.....	6.6	6.5	6.4	6.2	75	140,000	46,000	8,400	Slightly sour
131	.....	6.6	6.5	6.4	6.2	75	300,000	195,000	3,000	Slightly sour
X-3-1	.....	.....	.....	6.3	6.0	65	1,500,000	795,000	30,000	Curd
X-3-10	.....	.....	.....	6.3	6.0	65	110,000	65,000	29,700	Sour
X-3-11	.....	.....	.....	6.4	6.0	65	1,200,000	550,000	205,000	Sour
E-43-13	.....	.....	.....	6.5	6.0	65	200,000	120,000	20,000	Sour
124	.....	6.5	6.4	6.1	6.0	65	1,000 000	750,000	....	Curd
X-3-6	.....	.....	.....	6.0	5.8	55	700,000	448,000	210,000	Curd
X-3-7	.....	.....	.....	6.0	5.8	55	600,000	378,000	60,000	Curd
X-3-8	.....	.....	.....	6.2	5.8	55	11,000	8,000	....	Sour
E-43-15	.....	.....	.....	6.2	5.8	55	36,000	32,000	36,000	Sour
E-43-18	.....	.....	.....	6.0	5.8	55	216,000	185,000	31,000	Sour
E-43-14	.....	.....	.....	5.8	.....	50	1,350,000	....	....	Curd
E-33-5	6.5	6.4	6.4	5.8	.....	50	500,000	....	....	Curd
E-33-6	6.6	6.3	6.3	5.8	.....	50	500,000	....	....	Curd
E-33-7	.....	6.5	6.3	5.8	.....	50	150,000	....	....	Curd
E-35-35	6.5	6.3	6.0	5.8	.....	50	200,000	....	....	Curd
E-33-4	6.4	6.2	5.8	.....	.....	45	1,500,000	....	....	Curd
E-33-9	6.5	6.3	5.8	.....	.....	45	100,000	....	....	Curd
E-33-18	6.5	6.4	5.8	.....	.....	45	200,000	....	....	Curd
E-33-20	6.4	6.2	5.8	.....	.....	45	100,000	....	....	Curd
E-35-29	6.3	6.1	5.8	.....	.....	45	150,000	....	....	Curd
X	.....	5.8	.....	.....	.....	40	15,000,000	....	....	Curd
E-33-17	6.3	5.8	.....	.....	.....	40	300,000	....	....	Curd
E-33-21	6.3	5.8	.....	.....	.....	40	400,000	....	....	Curd
E-33-22	6.3	5.8	.....	.....	.....	40	200,000	....	....	Curd
E-33-24	6.3	5.8	.....	.....	.....	40	250,000	....	....	Curd
E-33-2	5.8	.....	.....	.....	.....	35	5,000,000	....	....	Curd
E-33-11	5.8	.....	.....	.....	.....	35	3,000,000	....	....	Curd
E-33-13	5.8	.....	.....	.....	.....	35	2,000,000	....	....	Curd
E-33-28	5.8	.....	.....	.....	.....	35	3,000,000	....	....	Curd

Table II

Summary of Table I.

Number of samples.	Score.	Average bacteria per cc.	Average acid bacteria per cc.	Average gelatin liquifying bacteria per cc.
5	100	11,000	3,500	1,650
5	95	23,000	6,200	2,400
5	90	48,000	10,300	3,900
5	85	78,600	18,900	34,800
5	75	136,000	71,800	8,000
5	65	802,000	456,000	71,200
5	55	312,000	177,000	76,200
5	50	440,000	....	....
5	45	410,000	....	....
4	35	3,000,000	....	....

In a previous paper the following provisional classification was used to divide the samples of milk into classes depending upon the use to which they are now put in dairy practice.

Table III

Provisional Classification of Milk.

Reading	pH	Score	Milk suited for.
1 hour	5.8	20	Condemning
2 hours	5.8	25	
3 hours	5.8	30	
4 hours	5.8	35	Skimming for butter making
5 hours	5.8	40	" " " "
6 hours	5.8	45	" " " "
7 hours	5.8	50	" " " "
8 hours	5.8	55	" " " "
8 hours	5.9	60	Condensing
8 hours	6.0	65	"
8 hours	6.1	70	"
8 hours	6.2	75	"
8 hours	6.3	80	Milk Plant supply
8 hours	6.4	85	Cheese Making
8 hours	6.5	90	" "
8 hours	6.6	95	" "
8 hours	6.7	100	" "
			" "

This interpretation of results will probably have to be changed somewhat as more extensive data are obtained. The standard for milk intended for condensing for instance will probably have to be shifted closer to that of milk suitable for milk plant supply and cheese making.

All of the samples tabulated in Table I were taken from the cans of farmers as the milk was delivered at the city milk plant.

By weighing the samples scoring 75 or better on the previous test into a separate vat the milk of excellent keeping quality may be separated from the milk of poor keeping quality, the better grade of milk being used for market milk purposes and the poorer grade for skimming. This plan may be used as a basis for paying a bonus on the better grade of milk. To divide the samples into two grades it would be necessary to make but one pH reading for each sample at the end of eight hours. A weekly record sheet is shown as Table IV.

Table IV

Weekly weighing sheet showing bonus system.

Patron.	2/7	2/8	2/9	2/10	2/11	2/12	2/13	Bonus paid on	No bonus paid on.
Mr. J.	**200**	250	150	200	200	250	200	1,200 lbs.	200 lbs.
Score	65	75	80	80	85	90	75		
Mr. N.	300	**250**	**150**	**200**	**200**	**300**	150	450 lbs.	1,100 lbs.
Score	75	70	60	50	55	50	75		
Mr. A.	**100**	150	**200**	150	200	**150**	**200**	500 lbs.	650 lbs.
Score	70	80	65	90	75	65	60		

Note: All milk weighed in bold figures are grade B. and receive no bonus. Remainder receive bonus as grade A milk.

This sheet is kept on the weighing floor and is a guide to the weigher in dumping milk. Milk is dumped into the Grade A or grade B tank depending upon the score for the previous day. The laboratory man after making daily tests records score upon sheet and places a bracket around weights of samples of grade B milk. If samples are not taken daily the patrons milk will remain in the class of last test until a retest is made.

By means of daily notification of the producer as to his score it is thought that his interest and cooperation might be secured and an increasing percentage of the daily milk brought to a score above 75.

MARKET MILK

Under the heading Market Milk may be considered the milk which has been delivered to the city milk plant and prepared for the market. Samples for laboratory examination should be taken as the milk is delivered at the home. The milk coming under this heading may be further classified as raw milk, pasteurized milk, and special milk.

Raw Market Milk. Raw market milk should be examined as to change in pH as soon as possible after the samples have been brought to the laboratory. As rigid a standard for raw market milk may be imposed as is required for the milk plant supply. If the milk is properly cooled as soon as received from the farm and is kept cool until delivered, the score by the pH method will be as high as when received. This is due to the fact that few of the bacteria will be able to develop in the cold milk and because some of the active organisms, if not actually killed by the exposure to low temperatures, have their growth inhibited to such an extent that the total activity of the bacteria present, when the milk is returned to a growing temperature, may be less than before the cooling period.

Pasteurized Milk. In examining pasteurized milk the ''change in pH'' method may be applied in the same way that it is applied in examining raw milk but the pasteurized sample should come up to a higher standard as a number of the active acid producing bacteria have been destroyed during the heating process. Efficiently pasteurized milk when stored at as low a temperature as 7°C. will remain in good condition for several days as judged by the pH test, but when held at a temperature of 21°C. it will be unfit for use in a short time. This is shown in Table V.

Table V

Effect of holding Pasteurized milk at 7°C. and 21°C.

Number.	Storage Temperature.	Time after delivery.	pH						Bacteria per cc.	% acid bacteria	% gelatin liquifying bacteria
			4 hours.	5 hours.	6 hours.	7 hours.	8 hours.	Score.			
15............	Start	....	.....	.....	.....	6.6	6.6	95	8,000	2	13
	7°C.	1 day	.....	.....	.....	6.6	6.4	85	10,000	10	10
	7°C.	2 day	.....	.....	6.6	6.4	6.2	75	40,000	20	75
21............	Start	....	.....	.....	6.5	6.4	6.3	80	250,000	50	0
	21°C.	1 day	.....	6.2	5.8	.....	.....	45	15,000,000	95	2
	21°C.	2 day	.....	.....	.....	.....	.....	30	41,000,000	95	0
23............	Start	....	.....	.....	6.7	6.7	6.6	95	30,000	40	3
	21°C.	1 day	.....	5.8	.....	.....	.....	40	24,000,000	90	1

It will be noticed that the pasteurized samples kept at a low temperature may become objectionable due to a high percentage of liquefiers without the condition being detected by this method, but that spoilage due to high temperatures may be quickly detected. Work which is under way will show the value and limitations of this test when applied to pasteurized milk.

Special milk. Under the heading special milk, may be considered milk which has been given special care in its production and handling; milk which has been modified as to chemical composition to suit the needs of infants and invalids; and milk which has been altered by removal of part of the water and addition of sugar for convenience in shipping and storage.

The results of testing the special milks mentioned above are given in Table VI.

Table VI

Special grades of milk tested by pH method.

Number.	Sample.	pH					Bacteria per cubic centimeter plate method.	
		5 hours.	6 hours.	7 hours.	8 hours.	Score.		
169E...........	Certified	.....	6.7	6.7	6.7	100	11,600	
169E...........	Certified	.....	6.7	6.7	6.7	100	5,000	Holstein
169E...........	Certified	.....	6.7	6.7	6.7	100	40,000	Walker Gordon
169E...........	Modified	.....	6.7	6.7	6.7	100	80,000	Walker Gordon
169E...........	Skim	6.5	6.4	6.4	6.2	75	50,000	Walker Gordon
169E...........	Cream	6.8	6.8	6.8	6.8	100	190,000	Walker Gordon
169E...........	Holstein	6.6	6.6	6.6	6.5	90	20,000	Walker Gordon
169E...........	Condensed	6.7	6.7	6.7	6.7	100	53,000	Borden's Eagle Brand
169E...........	Condensed	6.7	6.7	6.7	6.5	90	13,000	Borden's Leader Brand
169E...........	Baby Food	7.0	7.0	7.0	7.0	100	1,500	Mellin's

In this table the certified milk is seen to have a very good score. This is due to the special care which is exercised in its production and handling.

COMPARISON OF METHODS

To determine to what extent the pH and the more common methods of testing milk might be used to predict its actual keeping quality when stored at room temperature, 115 samples were collected at a city milk plant as delivered by the farmer patrons and tested as follows:

Keeping Quality. Milk was held at room temperature and tasted every two hours to detect the first appearance of souring.

pH Test. Tests were made and samples given a score as described in an earlier part of this paper.

Reductase test. Applied as described by Hastings (6).

Bacteriological count. Made according to the Standard Methods of Bacteriological Analysis of Milk. A. P. H. A., 1919.

The results of these tests are tabulated in Table VII.

Table VII

A comparison of the keeping quality of milk, pH score, reduction time and bacteriological count.

Number.	Time of Souring.	pH Score.	Reduction Time.	Bact. cc.
74-1	8 hours	35	15 minutes	4,000,000
74-2	8 hours	40	10 minutes	100,000,000
76-1	12 hours	45	25 minutes	2,500,000
76-2	12 hours	40	25 minutes	32,000,000
76-3	12 hours	45	30 minutes	50,000,000
76-4	12 hours	45	25 minutes	8,000,000
76-5	12 hours	45	215 minutes	1,400,000
76-6	12 hours	45	210 minutes	800,000
76-7	12 hours	45	150 minutes	600,000
76-8	12 hours	45	130 minutes	800,000
76-9	12 hours	45	150 minutes	5,000,000
76-10	12 hours	45	50 minutes	60,000,000
76-11	12 hours	45	20 minutes	22,000,000
76-12	12 hours	45	150 minutes	12,000,000
89-8	18 hours	55	120 minutes	1,200,000
89-9	18 hours	55	90 minutes	950,000
89-13	18 hours	55	90 minutes	10,000,000
89-14	18 hours	55	150 minutes	1,200,000
89-15	18 hours	55	150 minutes	3,800,000
79-1	18 hours	50	275 minutes	24,000,000
79-2	18 hours	45	100 minutes	3,000,000
79-3	18 hours	50	55 minutes	10,000,000
79-4	18 hours	45	35 minutes	2,000,000
79-5	18 hours	45	135 minutes	4,000,000
79-6	18 hours	50	200 minutes	2,500,000
79-7	18 hours	55	70 minutes	13,000,000
80-1	20 hours	50	170 minutes	36,000,000
80-2	20 hours	50	150 minutes	20,000,000
80-3	20 hours	55	290 minutes	1,000,000
80-4	20 hours	55	530 minutes	400,000
80-5	20 hours	55	360 minutes	700,000
80-6	20 hours	60	285 minutes	160,000
80-7	20 hours	55	360 minutes	80,000
80-8	20 hours	50	240 minutes	100,000
80-9	20 hours	55	310 minutes	1,300,000
80-10	20 hours	55	390 minutes	900,000
80-11	20 hours	55	160 minutes	1,600,000
80-12	20 hours	50	150 minutes	8,500,000
80-13	20 hours	50	180 minutes	4,000,000
80-14	20 hours	55	220 minutes	2,000,000
80-15	20 hours	55	240 minutes	2,000,000
89-11	20 hours	55	240 minutes	2,500,000
89-10	22 hours	65	180 minutes	650,000
89-16	22 hours	65	180 minutes	5,000,000
89-17	22 hours	65	240 minutes	1,000,000

Table VII Con.

Number.	Time of Souring.	pH Score.	Reduction Time.	Bact. cc.
81-1	22 hours	60	420 minutes	100,000
81-2	22 hours	55	160 minutes	3,000,000
81-3	22 hours	50	265 minutes	300,000
81-4	22 hours	55	290 minutes	32,000,000
81-5	22 hours	50	360 minutes	500,000
81-6	22 hours	55	300 minutes	5,000,000
81-7	22 hours	50	325 minutes	100,000
81-8	22 hours	55	360 minutes	50,000
81-9	22 hours	85	310 minutes	100,000
81-10	22 hours	65	285 minutes	2,500,000
81-11	22 hours	80	410 minutes	10,000
81-12	22 hours	75	360 minutes	1,000,000
81-13	22 hours	85	460 minutes	200,000
82-1	24 hours	65	300 minutes	4,800,000
82-2	24 hours	75	530 minutes	300,000
82-3	24 hours	75	310 minutes	300,000
82-4	24 hours	95	355 minutes	260,000
82-5	24 hours	95	450 minutes	100,000
82-6	24 hours	55	450 minutes	80,000
82-7	24 hours	65	325 minutes	170,000
82-8	24 hours	75	425 minutes	1,000,000
89-4	24 hours	100	480 minutes	250,000
89-5	24 hours	95	300 minutes	75,000
89-7	24 hours	90	180 minutes	2,700,000
89-12	24 hours	90	330 minutes	5,000
83-1	26 hours	95	460 minutes	50,000
83-2	26 hours	100	420 minutes	160,000
83-3	26 hours	100	290 minutes	650,000
83-4	26 hours	95	290 minutes	1,000,000
83-5	26 hours	95	420 minutes	150,000
83-6	26 hours	85	445 minutes	320,000
83-7	26 hours	95	450 minutes	100,000
83-8	26 hours	95	450 minutes	400,000
83-9	26 hours	95	600 minutes	50,000
89-28	26 hours	100	600 minutes	7,000
89-29	26 hours	100	420 minutes	5,000
89-30	26 hours	85	390 minutes	5,000
84-1	28 hours	85	460 minutes	400,000
84-2	28 hours	75	500 minutes	16,000,000
84-3	28 hours	85	530 minutes	30,000
84-4	28 hours	95	540 minutes	60,000
84-5	28 hours	95	540 minutes	50,000
84-6	28 hours	95	450 minutes	120,000
84-7	28 hours	95	400 minutes	10,000
84-8	28 hours	85	390 minutes	10,000
84-9	28 hours	90	600 minutes	10,000
89-1	28 hours	95	300 minutes	200,000
89-6	28 hours	100	480 minutes	12,000
89-19	28 hours	100	495 minutes	10,000
89-23	28 hours	100	480 minutes	13,000
89-25	28 hours	100	480 minutes	23,000
89-3	28 hours	100	495 minutes	30,000
85-1	30 hours	85	470 minutes	2,000,000
85-2	30 hours	95	355 minutes	60,000
85-3	30 hours	100	500 minutes	40,000
85-4	30 hours	100	540 minutes	440,000
85-5	30 hours	95	450 minutes	900,000
85-6	30 hours	100	500 minutes	300,000
85-7	30 hours	100	540 minutes	170,000
85-8	30 hours	95	365 minutes	100,000
85-9	30 hours	95	540 minutes	80,000
85-10	30 hours	95	600 minutes	110,000
89-2	30 hours	100	660 minutes	22,500
89-18	30 hours	100	660 minutes	3,000
89-20	30 hours	100	600 minutes	6,000
89-21	30 hours	100	660 minutes	1,260,000
89-22	30 hours	100	420 minutes	8,000
89-24	30 hours	100	495 minutes	63,000
89-26	30 hours	100	660 minutes	9,000
89-27	30 hours	100	660 minutes	5,000

The average time of souring, pH score, reduction time, and bacterial count of samples appearing in Table VII is retabulated in Table VIII. The high bacterial counts of several samples with scores of 75 to 100 make it appear that the majority of these samples have much higher counts then is actually the case. One count of a sample of milk souring in 28 hours has been disregarded because it raised the average of the samples in the group by over 1,000,000.

Table VIII

The average time of souring, pH score, reduction time and bacterial count of samples appearing in Table VII.

Time of Souring.	pH Score.	Reduction Time.	Bact. per cc.	No. of samples.
8 hours............	37.5	12.5	52,000,000	2.
12 hours............	45.	98.	16,258,000	12.
18 hours............	51.	123.	6,304,000	12.
20 hours............	54.	267.	5,075,000	16.
22 hours............	62.	306.	3,219,000	16.
24 hours............	81.	370.	920,000	12.
26 hours............	95.	436.	241,000	12.
28 hours............	93.	476.	*100,000	15.
30 hours............	98.	537.	310,000	18.

*One sample with a count of 16,000,000 was ignored in making average.

An examination of Table VII shows that all of the methods studied are satisfactory indicators of samples of milk with very good keeping quality or samples with very poor keeping quality. The real test of the various methods, however, is; which one will indicate the proper position of the samples just on the border line between the good and the bad?

The writer with assistance from members of the department has selected 24 hours as the time that milk should be expected to remain sweet after delivery in the home and storage at room temperature, 70°F. The samples of milk souring in 22 hours, 24 hours, and 26 hours then, may be considered on the border line between good and bad milk.

The correlation ratio* between the actual keeping quality of the samples of milk selected as above, and their pH score, reduction time and bacteriological count is as follows:

pH score............................	.75
Reduction time........................	.52
Bacteriological count	—.25

When used to place the samples of milk as to their keeping quality the reduction time is thus seen to be subjected to about 100 percent greater error than is the pH score. The bacteriological count is subject to about 300 percent greater error.

Hastings and Davenport (7) in a recent comparison of the relative value of the methylen blue reduction test, the brom-thymol blue test and the brom-cresol purple test arrive at the following conclusions.

"In a comparison of the three tests, methylene blue reduction, brom-thymol blue, and brom-cresol purple for the determination of the keeping quality of milk, it is shown that the methylene blue reduction test is preferable because of its greater sensitiveness to biological differences in milks;

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*See Elements of Statistical Methods—King. Introduction to Mathematical Statistics—West.

because it measures the number of bacteria rather than the by-products of their growth; and because of its simplicity and practicable advantages.''

The brom-thymol blue test mentioned above can be compared in no way with the pH method of testing milk given in this and previous papers for the following reasons:

(1) The milk-broth-indicator mixture is incubated for only 2 hours instead of the 8 hours necessary in our method. Changes in color which are used as an index of the condition of the milk seldom develop before the third hour.

(2) The readings were not made by comparing unknowns with standards of known pH.

As it was impossible to make microscopic examination of the samples of milk tabulated in Table VII at the time the other tests were made the data presented in Table VIII were collected to show the relation between the actual keeping quality of the milk and the microscopic determination of individual bacteria and groups of bacteria.

Table VIII

A comparison of the keeping quality of milk and the microscopic determination of individual bacteria and groups of bacteria.

Time of Souring at 70cF.	Microscopic Method.		Number of samples.
	Avg. No. of individual bacteria.	Average number of ''groups''.	
8 hours	77,000,000	18,000,000	3
10 hours	60,000,000	5,000,000	5
12 hours	19,000,000	4,900,000	2
14 hours	12,500,000	2,700,000	5
16 hours	2,600,000	500,000	7
18 hours	4,600,000	750,000	5
20 hours	20,500,000	1,700,000	8
22 hours	3,000,000	500,000	6
24 hours	210,000	44,000	5
26 hours	180,000	41,000	7
28 hours	82,000	22,000	2
30 hours	132,000	19,000	3
32 hours	40,000	32,000	4

The microscopic counts of the sixty-one samples tabulated above show considerable error if used to predict the keeping quality of the samples of milk which they represent.

SUMMARY AND CONCLUSIONS

The technique for determining the keeping quality of milk by the pH method is presented.

Apparatus for simplifying the method which have been devised at this laboratory are described.

In the past a number of investigators have come forward with new methods for testing milk. The tendency has been to try to make new methods check as closely as possible with the bacterial count, and several good methods for the determination of keeping quality have been thrown into the discard because of their failure to check with the counts. The writer makes no claims that the pH method checks closely with the bacterial count, though results show that it does check in a general way.

The pH method checks very well with the actual keeping quality of the milk.

A plan for grading milk and of paying a bonus to farmers furnishing milk with unusual keeping quality is presented.

A comparison of the **actual keeping quality** of 115 samples of milk with results obtained by applying the reductase test, pH test, and bacterial count gives results very much in favor of the pH test.

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FOREWORD.

This bulletin is one of a series bearing upon the diseases of celery. A report on the Septoria Leaf Spot has already been issued as Special Bulletin 77. The present bulletin discusses a disease which, in general, is less serious than Septoria Leaf Spot, but which frequently causes serious losses. Publications on at least two other celery diseases are contemplated in the near future. The work reported in this article is a result of investigations extending over a period of several years by C. W. Bennett, who for part of this period was a graduate student at Michigan Agricultural College, and later an instructor in the Department of Botany. The work was suggested by Dr. G. H. Coons, and has been carried out under his direction.

E. A. BESSEY.

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A PHOMA ROOT ROT OF CELERY*.

Technical Bulletin No. 53.

BY C. W. BENNETT.

Introduction.

There are several million acres of muck lands in Michigan which constitute an appreciable percentage of the possible farming area of the State. Some of this is highly improved and forms some of the most valuable land to be found in any of the great agricultural sections of the country. This type of soil, on account of its high organic content and physical properties, is peculiarly adapted to the growing of truck crops. Celery, cabbage, lettuce, and onions, in particular, are crops which thrive well and which yield good returns. The growing of these crops for the markets of Chicago, Detroit, and other large cities of the north central and middle west, constitutes an important part of Michigan agriculture.

On account of the liberal returns per acre and the brisk market demand, celery has become a leading crop on muck land favorably situated in relation to markets. The high organic content of muck soil is conducive to rapid vegetative growth which produces the very best quality in celery and also enables the grower to put his product on the market early in the season. In some areas two or three crops are grown on the same soil each year. In such cases the second and third crops are put in between rows just before the preceding crop is placed in boards for bleaching. Thus, the land is in celery the entire growing season. Along with this intensive culture, the value of the crop has led to an almost complete absence of rotation in many of the chief celery growing districts. Not infrequently do we find fields which have grown celery continuously for a period of more than thirty years, the fertility of the soil not only being maintained but greatly improved by liberal application of manure.

The absence of rotation, the interchange of plants, and the procuring of seed from a great many sources has resulted in the introduction of practically every disease known to the celery plant. One of the most recent of these invaders is a Phoma disease, which, in Michigan, was first discovered at Kalamazoo in the spring of 1914 by Dr. G. H. Coons of the Michigan Agricultural College (2). The disease, since its introduction has not spread rapidly in epidemic form, but in several cases it has been very destructive on small acreages. These destructive outbreaks have seemed serious enough to warrant a systematic study of the disease with a view to adding something to the knowledge of its relation to weather and soil conditions and to our methods of coping with the problem which this disease presents to celery growers.

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*Presented to the Faculty of the Graduate School of the Michigan Agricultural College as a thesis in partial fulfillment of the requirements for the degree of Master of Science.

The writer wishes to acknowledge his indebtedness to Dr. E. A. Bessey and to Dr. G. H. Coons of the Department of Botany for valuable aid and suggestions during the course of this work as well as for aid in the preparation of the manuscript.

NAME OF THE DISEASE.

This disease, like many others, is known by a number of common names. In Germany it is called ''Schorfkrankheit'' and the name ''Scab'' has been applied in this country. ''Root Rot'' is a term which is commonly used but sometimes confused with rot due to Sclerotinia and other causes. In choosing a common name for a disease one should be selected which will not be confused with other troubles and one which is as descriptive as the nature of the signs permits. The diseased area is not typically scabby, but simply composed of dead tissue. Since this is true, the term ''Scab'' seems inappropriate for the trouble as it occurs in America; on turnip rooted celery the term may be more descriptive. The roots constitute one of the chief points of attack and it seems that no term is more fitting than Root Rot. To avoid confusion with other Root Rots of celery we suggest that the disease be called Phoma Root Rot, the causal organism being, as will be shown later, a species of Phoma.

HISTORY AND DISTRIBUTION.

There is considerable difficulty in determining the approximate time at which Phoma Root Rot first made its appearance as a disease of celery, and in tracing the history of the trouble. While the same disease has been described by certain European investigators on celeriac in Germany, Holland and France, little has been reported regarding its occurrence in this country. It is hardly probable that this is due to a recent introduction of the pathogen, or to a limited distribution of the disease. Numerous references in literature to root rots of celery, all presenting much the same pathological aspects, make it more plausible to believe that the disease has been present in certain celery districts for a number of years, and that it is generally distributed through the celery growing districts of the east and east central parts of the United States. Working as it does beneath the surface of the soil, the true cause of the disease has probably escaped observers because of its rather obscure nature and because of confusion with other diseases.

Aside from a Phyllosticta leaf spot, reported by Halsted (4), no description of anything similar to this disease seems to have been made until Van Hook (7) discovered and described a root rot of celery from the celery districts of Ohio. He did not identify the organism causing the trouble, but mentioned having found a species of Rhizoctonia in the diseased tissue. He states, however, that he does not believe that Rhizoctonia alone was responsible for the disease. Nor can the writer believe that any species of Rhizoctonia had a part other than as a secondary organism coming in after the disease had been initiated by another fungus. In the writer's work with diseased plants, Rhizoctonia has quite frequently been associated with diseased conditions. Inoculations from several typical Rhizoctonia isolations from celery, and with *Rhizoctonia solani* and a Rhizoctonia from milkweed have given no results which would indicate that any of these forms are markedly pathogenic to celery. Van Hook made inoculations with isolations of Rhizoctonia which he found associated with celery root rot, but was unable to obtain infection. Small celery plants, of course, are sometimes attacked by Rhizoctonia as reported by Peltier* and others, but there is at present no conclusive evidence that any species of this genus causes any serious disease of plants which have passed the seedling stage.

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* Peltier, G. L. Parasitic Rhizoctonias in America. Ill. Agr. Exp. Sta. Bul. 189. 1916.

Van Hook's descriptions, his photographs of diseased plants, and the environmental conditions under which the disease became destructive, furnish evidence conclusive enough to justify the assumption that he was dealing with the Phoma Root Rot which has been reported from the celery growing regions of Michigan and New York.

In 1914, Coons (2) discovered Phoma Root Rot in the celery fields at Kalamazoo and in 1916 at Byron Center, Michigan, where the disease had been seen by growers for several years. The following seasons the disease was again found in fields at these places, and it has been present, causing more or less loss, each season since it was first noted. In 1918 the author observed cases of the disease at North Muskegon and Portage, Michigan.

Dye and Whetzel† in 1918 reported the disease as present in New York State. Again in 1919‡ Phoma Root Rot was reported from the celery districts of Ohio, where it seems the disease is more or less prevalent, depending on weather and soil conditions. As yet, no mention of the disease has been made from the southern celery growing sections or from the Pacific Coast.

Outside of the United States, our knowledge of the disease is restricted to the northwestern part of Europe. Klebahn (5) described Phoma Root Rot on celeriac grown in Hamburg lowlands. It seems to have a general distribution over Holland and southern Germany, where it has caused serious loss to the growers of turnip-rooted celery. Quanjer and Slagter (6) described the disease from Holland and state that it is generally distributed in that country.

ECONOMIC IMPORTANCE.

The sporadic occurrence of this disease makes it impossible to give even an approximate estimate of annual loss. The seriousness of the attack after infection depends almost entirely on environmental conditions. In cool, wet seasons, the loss may reach 100 per cent in an infested district; under other conditions, the loss may be negligible.

The disease in America has never been so serious as in Europe. Klebahn (5) and Quanjer and Slagter (5) report considerable damage to celeriac occurring at more frequent intervals than has been noted in America. Many plants are rotted off at the base, while the damage done by stunting and pruning away of the outer leaves, calls for serious consideration, reducing as it does the market value of stalks so greatly.

Several rather severe outbreaks of this disease have been recorded in America in certain localities. Van Hook reports that in the celery districts of Ohio in 1902 one grower suffered a loss of 75 per cent of his crop; minor losses were reported from other sections. At Kalamazoo, Michigan, in 1914, and again in 1915§ the first crop on an area of three acres was a complete loss. At Kalamazoo and Byron Center, Coons (3) states that the disease was very severe in the spring of 1917. In the past three seasons the disease has been present in a number of celery fields which have been inspected, but diseased plants have shown nothing more than black rings around the base. These seasons have been rather dry and warm in the early part of the summer; this no doubt accounts for the scarcity of the disease during these years. Where the disease producing organism is known to be present, growers should expect to encounter loss in cool, wet seasons if due precautions for protection are not taken.

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† Verbal statement to Dr. G. H. Coons.

‡ Plant Disease Bulletin, Supplement 3, p. 108, 1919. "Scab, caused by Phoma apiicola Speg. (sic) was recorded on celery from Ohio."

§ Verbal report to the author.

HOSTS.

So far as the writer has been able to discover by a careful survey of the literature on the subject, this disease has been reported only on celery and celeriac (*Apium graveolens L.*). Other Phomas have been reported on species of the Umbelliferae, but in many cases the available descriptions are too meager to admit of satisfactory comparison with the one on celery. It is, of course, entirely possible that this organism may have been reported on other species of plants. The genus Phoma embraces so many little-known forms, with present descriptions so inadequate, that, until a more comprehensive study of the genus is made, it will be impossible to determine the validity and host range of many of the parasitic species.

Inoculation experiments leave no doubt as to the ability of the fungus to attack plants other than celery. Its potentialities along this line have been tested by inoculation of a number of species of the Umbelliferae family with pure cultures of the causal organism.

Plants, nearly related to celery and of economic importance, were inoculated with pure cultures of the pathogen, under conditions very favorable to the production of the disease on celery. Inoculation of carrot (*Daucus carota*) produced black, sunken spots on the roots and a killing of the outer leaves. Pycnidia were found scattered over the diseased parts. (*Pl. IV. Fig. a*).

Parsnip (*Pastinaca sativa*), while it is by no means immune, seems to be less susceptible than carrot. The region of invasion was largely confined to the upper part of the root and to the base of the leaf stalks. The diseased parts were typically dark brown or black. On the root the epidermis was broken and the underlying tissue invaded, which resulted in a ''cankered'' area. Invasion was very slow and the damage slight, except as the diseased spots disfigured the roots. (*Pl. IV. Figs. b and d*).

Under greenhouse conditions Moss-Curled parsley (*Carum petroselinum*) and celery seem to be equally susceptible to attack of the fungus. Young plants were killed by being rotted off at the base and older plants were severly attacked, showing signs similar to those on celery. Plate IV, Fig. c. shows a typical plant of a series of inoculations. The black crown is characteristic. Pycnidia of the pathogen were produced upon all diseased parts. Although it has not been reported, it would not be surprising to find this disease doing damage to parsley under field conditions, particularly in trucking and seed-producing districts where celery and parsley are grown extensively, with little or no rotation with other crops.

The attacks of the fungus on caraway (*Carum carvi*) were very weak. A few leaves were killed by basal invasion but the region of attack is usually limited. Poison hemlock, (*Conium maculatum*) and dill (*Anethum graveolens*) have failed to show any lesions in spite of heavy inoculation with mycelium and spores.

SIGNS OF THE DISEASE.

GENERAL.

Cases of mild infection are often impossible to detect on celery, unless the plants are removed from the soil and examined for dark discolorations. Above ground, the first indication of this disease is the dying of a few outer leaves. Often one or two withered leaves lying on the ground, but still attached to the plant, betray the presence of the disease, while the remainder of the plant has all the appearance of a normal, undiseased individual. As invasion progresses, more leaves may die and fall to the ground. The plant takes on a general unthrifty appearance and, quite often, remains stunted throughout its period of growth. In the case of severe attacks, plants topple over, so completely are the crowns and roots destroyed.

ON LEAVES.

Under Michigan conditions, natural infection of the leaves has not been noted, and if it does take place it is probably of rare occurrence. Wherever the disease has appeared in America, it seems to have been restricted to underground parts. In literature and references pertaining to celery diseases, there are only two citations of an occurrence of an organism of a Phoma or Phyllosticta type on leaves of celery. Halsted (4) described a Phyllosticta on celery leaves, which closely resembles the organism causing Phoma Root Rot, and which produced a leaf-spot such as can be produced by inoculation, under the proper environmental conditions, with the root rot organism.

In Holland, Klebahn (5) found the disease on celeriac leaves and on the flowering parts, and also discovered pycnidia of the pathogen on the seeds.

Given the proper conditions, the fungus is capable of attacking the leaves. Spraying with spores outside and in the greenhouse has not resulted in leaf infection. Only a small amount of infection has been produced by spraying the plants with a spore suspension and placing them under battery jars. Much more uniform infection has been obtained by first germinating the spores, then placing them on the leaves under small bits of wet cotton. On leaves inoculated in this manner, signs of the disease began to appear after two days. The results of infection may be of several kinds, depending on conditions. If there is not too great a quantity of moisture present there is first produced a light colored spot which later turns into an irregular red blotch. Given more moisture, the fungus, possibly by the aid of other organisms, produces soft, water-soaked areas, which are often studded with pycnidia. In the first type of spot, fruiting bodies begin to be formed in the mesophyll of the leaf, but seldom reach maturity unless the leaves are subjected to exceptionally moist conditions. The progress of the disease has been slow under all conditions maintained, and individual spots cease to spread when the plant is taken out of a moist atmosphere, and more or less normal relations restored. Leaves that have been killed by invasion at the base, often show pycnidia on the petioles and blades, after remaining on damp soil for a time, which indicates that the fungus is not selective as to the part of the plant attacked, but is governed chiefly by environmental factors.

Inoculation experiments, and observations on the disease in the field, establish clearly that climatic relations in Michigan are not favorable to the development of the leaf-spot phase. In no place, either in America or Europe, has leaf infection been reported as common. The pathological significance lies in the bearing which leaf and flower infection may have on the dissemination of the disease producing fungus.

ON CROWN AND ROOTS OF PLANTS.

The chief loss to the celery crop from this disease comes from attacks on the roots and crown of the celery plant. In the incipient stages of the disease, there is usually a bluish-green discoloration of diseased parts; which, as invasion continues, gives rise to a black, scurfy surface. A bluish-green border, more marked on the leaf stalks than on any other part, is usually found around these blackened areas. The fungus may confine its ravages to the outer part of the crown and produce a black ring of diseased tissue. This kind of an attack, by killing the epidermal and neighboring cells, often leads to large cracks in the crown and bases of the leaf petiole, as the plant continues to grow and expand from within. The course of the disease after infection depends entirely on environmental conditions. The plant may attain normal size and reach maturity, with only a black ring around the crown to indicate the presence of the disease. In other cases, the plant may rot off at the crown or the roots may be attacked and destroyed, leaving the plant to fall over, or to maintain itself by means of new roots which may be shot out from the diseased base. Plants of this latter class are usually stunted and are easily pulled out of the soil. They exhibit a black, ragged, cone-shaped butt which is invariably studded with black fruiting bodies of the pathogen.

In some cases, when the plants are deeply set, the attack may be confined to the leaf stalks in the region where they come in contact with the first inch or two of surface soil. In such instances, a killing of the outer leaves usually occurs. In most cases, the disease spreads to the crown and roots where the work of destruction is continued.

Root attacks are most severe in close proximity to the crown. There is rarely a general attack on the entire root system. Typically, infection takes place at some point near the base of the leaves, and spreads down and around the basal portion of the plant, involving the roots as it progresses. Those roots which are near the surface are more subject to attacks along their entire length than are those which extend down deep in to the soil. The disease on the roots is characterized by a brownish discoloration. The black surface, so typical of the disease on other parts of the plant, is also noted on the larger roots; small roots usually disintegrate before this color appears.

ETIOLOGY.

MORPHOLOGY OF THE CASUAL ORGANISM.

Mycelium

Within the tissue of the host plant, the mycelium is composed of septate threads, sparingly branched, and comparatively small; averaging between 3-4 microns in diameter. In young hyphae, cross walls are rare and the threads are very uniform throughout. With age, the hyphae sometimes increase in diameter, and the cells may bulge slightly as the cell walls thicken, and as the septa become more numerous. Very young hyphae are hyaline and the cell contents finely granular; older threads are vacuolate and often densely granular within.

In pure culture, the organism is subject to great variation in size of threads in thickness and color of cell walls, and in structure of cell contents. New hyphae vary from 2-4 microns in diameter. These become very closely septate, and the cells bulge and increase in size, until they are large spherical bodies, 20 or more microns in thickness. The cell walls are rather thick and have a dark-brown color. When the mycelium comes in contact with glass, it forms a black mass of thich walled cells which closely adheres to the smooth surface; in liquid cultures it forms a black ring immediately above the surface of the culture medium. Old cultures, on favorable media, form black compact masses of densely interwoven threads approaching a pseudoparenchymatous tissue. On dextrose agar, sclerotium-like bodies, several millimeters in diameter, are sometimes produced in the mass and near the surface of mycelial growth. These very much resemble sclerotia of the genus Sclerotinia. Sectioning, however, reveals the same context throughout; the entire structure is composed of dark brown cells closely compacted and cemented together. Klebahn, in addition to finding these bodies in pure culture, has noted them on diseased plants.

Pycnidia

Pycnidia are produced singly, either scattered or clustered on the surface of the host. Mycelial development around the pycnidium is sparce; nothing approaching a stroma has been observed. Young pycnidia are hyaline; older ones vary from brown to black. A few pycnidia are more or less spherical, but more commonly they are considerably depressed; all are very symmetrical. In size they measure 80-100 x 100-250 microns. The pycnidia walls vary in thickness from 6 to 8 microns. The neck is cylindrical or expanded at the base and top. Pycnidia usually originate immediately below the epidermis; as they increase in size, they may push outward, until, at maturity, they are firmly seated on the surface with only the base imbedded in the host tissue; or they may remain imbedded in the host tissue with only the neck exposed.

The pycnidium has its beginning in a tangled weft of hyphae which rounds out into a globose fruiting body. The first part to darken is the neck of the ostiole which is conspicuous as a black ring, even before any part of the pycnidium becomes superficial. The remainder of the pycnidial wall is hyaline until after the spores are formed. Then there is a deposition of brown coloring matter in the outer layer of cells which produces the dark colored pycnidium. The greater part of the black outer portion of the pycnidial wall consists of a layer of large, rather thick walled cells. This is rarely more than one cell in thickness. Near the base of the ostiole, the wall begins to increase in thickness, until the wall of the neck itself is two to three cells thick. To this greater number of thick walled cells, is partly due the darker color of the pycnidial neck. Within, covering the internal surface and extending well up into the neck of the pycnidium, is a layer of thin-walled cells filled with dense masses of protoplasm. These give rise to minute conidiophores which, in turn, give rise to spores by constriction and formation of cross walls near their tips.

Spores

Spores of *Phoma apiicola* are small rod-shaped, thin-walled, hyaline bodies, measuring 3-3.8 x 1-1.6 microns. Staining discloses the presence of vacuoles which are surrounded by cytoplasm having a finely granular structure. The size of spores on the host plants does not vary to any considerable degree. This uniformity apparently holds true with the organism very generally, as the following table of measurements by different investigators will show.

SPORE AND PYCNIDIUM MEASUREMENT.

	Spore	*Pycnidium*
Klebahn	3-4 x 1.2—1.8 microns	90-240 microns
Quanjer and Slagter	4 x 1.5 microns	98-210 microns
Author	3-3.8 x 1-1.6 microns	80-100 x 100-250 microns

The pycnidia, as shown by the above table, are subject to great variation in size. Quanjer and Slagter (6) found that spores produced in pure culture were smaller than those on the host, a thing which has not been noted in any culture used in this work.

PROOF OF PATHOGENICITY.

The organism causing "Scab" of celeriac was isolated by Klebahn (5) and its pathogenicity proved by inoculation experiments. Coons (2) isolated a Phoma from diseased celery plants and proved its causal relationship to Root Rot. Regarding this organism he says: "This fungus was obtained in pure culture and typical lesions were obtained in inoculation experiments. The etiological relation of the Phoma thus obtained has been fully established."

The author has obtained a Phoma from celery from a number of sources. Single spore isolations have been made from diseased plants from Kalamazoo, Portage, and North Muskegon, as well as from a number of diseased plants which were found in the greenhouse at the Michigan Agricultural College. Inoculations with these cultures have given characteristically diseased plants in a large percentage of cases. The organism has been reisolated from celery, parsnip, and parsley and the identity of the different cultures proved by comparison of cultural characteristics and by inoculation followed by typical signs of disease. Repeated inoculations and isolations leave no doubt as to the pathogenicity of the organism and its causal relationship to the disease.

NAME OF ORGANISM.

European writers have been unanimous in ascribing the cause of "Scab" of celeriac to *Phoma apiicola* Kleb. A culture of this organism was obtained from Dr. Johanna Westerdijk of the Centralstelle für Pilzkulturen, Amsterdam, by Dr. G. H. Coons who compared this culture with the Phoma which he isolated from celery. As a result of this comparison he states that, "The fungus (the one isolated in Michigan) in culture and pathological habit greatly resembles *Phoma apiicola* described by Klebahn as producing the 'Scab' of Celeriac."

The author has further compared this European culture with the ones which have been isolated in Michigan in an effort to find morphological or physiological differences. In the earlier work it was found that the European culture produced distinctly lighter colored mycelium. Later it was found that Michigan strains grown on artificial media lost color so that the cultures from the two different sources could not be separated on the basis of any color difference. Pycnidial and spore differences have not been found, and each strain has exactly the same host range, both attacking celery, celeriac, parsnip, carrot, parsley and caraway. Thus, the European fungus which causes "Scab" of celeriac seems to be identical with the Michigan Root Rot organism.

RELATION OF PARASITE TO HOST.

METHOD OF INFECTION.

The factors involved in the physiology of parasitism have been baffling problems which investigators have attacked with varying degrees of success every since the study of plant diseases attracted scientific research. Much of the work done has hinged around the method by which the parasite enters the host and around relations of the pathogen to the internal tissues of the host. It is to be hoped that a thorough knowledge of these phases will aid in the discovery of at least some of the fundamental factors which constitute the difference between parasites and saprophytes. Aside from the scientific value connected with this kind of investigation, there is often considerable practical significance attached to the method of host penetration and invasion.

Parasites employ a number of different methods in entering host tissue. Germ tubes may enter through stomata, as Gregory* has shown for *Plasmopora viticola*, and as Pool and McKay† have shown for *Cercospora beticola.* Other natural openings are often very important. Wounds break down the plant's defensive equipment and, with many parasites, are the path of invasion. Still other organisms enter by boring directly through the epidermal cell walls. In the case of the *Botrytis* of lily, Ward‡ very early believed that the fungus gained entrance by dissolving the cell walls by means of a ''ferment substance'', an observation which has been confirmed repeatedly and which has been found to be true for a great number of other plant pathogens.

Whether or not all organisms which penetrate cell walls employ some kind of dissolving substance as they come in contact with the host, is not definitely known. It is possible that the substances are not necessary for all parasites, Hawkins and Harvey§ think that in *Pythium de Baryanum* they have an organism capable of exerting enough mechanical pressure to enable the threads to push their way through the cell wall.

With a view to determining the relation of the Phoma Root Rot organism to its host in the early stages of infection, a number of inoculations and microscopic studies have been conducted. Virulent strains of this parasite uniformly give infection regardless of whether spores or mycelium are used as the inoculum, but on account of the greater uniformity of time required for penetration spores have been used for studying methods of infection.

Leaf and petiole inoculations have been made to avoid the difficulty of making observations on crowns and roots. The spores were first germinated in water, then bits of filter paper were soaked in this spore suspension and placed on the plant under flecks of wet cotton. The spots inoculated were examined at different times by stripping off pieces of epidermis, or by placing bits of leaves under the microscope. In this way, it was possible to study relation of host and parasite under high power without resorting to stains.

Forty-eight hours after inoculation the germ tubes were found to have entered the host. The method of entrance was a direct penetration of the epidermal cell walls by the fungus hyphae. The threads pass into the cell lumen and penetrate other cell walls as they are encountered. No cases of penetration between cells, by wedging apart of cell walls or by dissolving the cementing substances were discovered. A few cases of stomatal entrance were noted but these were not numerous enough to denote any special attraction on the part of the stomata for the fungus. Those tubes which entered in this manner probably did so by chance rather than as an easy method of gaining entrance to the host tissue. As the fungus normally attacks the underground parts where stomata are scarce or lacking, it is obvious that methods of entrance must be confined to other natural openings, to wounds, or to direct penetration. These observations establish the fact that the fungus is capable of making its own openings in the leaf-blade and petiole. The same is doubtless true in the case of roots and crown.

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* Gregory, C. T. Spore germination and infection with Plasmopora viticola. Phytopath. 2:235-249. 1912.

† Pool. Venus W. and M. B. McKay. Relation of stomatal movement to infection by Cercospora beticola. Jour. Agr. Res. 5:1011-1038. 1916.

‡ Ward, Marshall, H. A lily disease. Ann. Bot. 2:319-382. 1888.

§ Hawkins, Lon H. and R. B. Harvey. Physiological Study of the Parasitism of Pythium de Baryanum Hesse on the potato tuber. Jour. Agr. Res. 18:275-298. 1919.

With young plants, 100 per cent infection is quite frequently obtained; older plants, when inoculated, often fail to take the disease. This observation has been made repeatedly with greenhouse plants. Young seedlings are subject to rapid infection. As the plants increase in age, indications of extreme susceptibility become less marked, though age by no means renders them immune. Full grown plants can be made to take the disease under certain conditions. As the plants become older the tissues become tougher and no doubt offer more resistance to invasions of this fungus. Breaks in the epidermis under these conditions would offer opportunity for the pathogen to gain a foothold.

To determine the effect which wounding would have on the percentage of infection in the case of older individuals, 50 plants were selected and wounded in the region of the crown by scratching into the tissue with a sharp needle. Bits of mycelium were placed in direct contact with these breaks in the epidermis. At the same time, an equal number of checks was inoculated by placing mycelium in contact with unbroken tissue. The plants were kept under conditions favorable for the progress of the disease. At the end of two months, 48 of the 50 wounded plants had developed black rings around the crowns, and a large number of roots had been lost. Of the check plants, 32 of the total 50 showed typical signs of the disease, but the invasions were more restricted and much less serious in their effect on the normal functioning of the host plants.

Under average conditions in the field, wounds due to insect bites, fungus invasion, mechanical injuries, etc., are common. Such injuries in all probability are an aid in admitting the root rot fungus, but by far the greater percentage of infection probably takes place through the unbroken epidermis. Especially is this true in the case of young plants which may suffer a high percentage of infections. Older plants which offer more resistance to invasions are no doubt less susceptible when they present an unbroken surface.

PATHOLOGICAL HISTOLOGY.

Previous investigation by Klebahn (5) has shown that the Phoma Root Rot organism grows both intercellularly and intracellularly. This point was confirmed early in the course of the present work, and an attempt was made to determine something of the effect of the pathogen on the individual host cells. Liquid cultures in which the fungus had grown, extracts from mycelium, and alcoholic precipitates from both of these types of substances have produced no perceptible effect on raw sterile celery when pieces were immersed in such solutions. It was found that enzymes which will dissolve cellulose or pectin and allow the fungus to make progress between or through cells or which would cause a falling apart of the cells of celery tissue through dissolution of the middle lamella, if produced by the fungus, are at least not present in sufficient quantities to show noticeable results in experiments of this kind. Sections of diseased plants show the hyphae ramifying through all parts of the tissue, forming a perfect network of threads through the cell walls and protoplasm. Apparently hyphae are capable of penetrating cell walls at any point at which they come in contact and of running through cell walls, protoplasm or intercellular spaces as these are encountered. Hyphae have been found in all the various tissues of the celery plant. In the later stages of disease, mycelium sometimes even produces extensive growth in the vascular system. Neither stained nor unstained sections reveal injury preceding invasion as is noted with many rot producing organisms. Even after penetration the cell is not immediately destroyed; many invaded cells, but for the presence of mycelium, could not be distinguished from cells of normal unattacked tissue. The first indication of change in the invaded cells comes about through a disintegration of protoplasm, followed by production of brown coloring matter in the cell walls preceding a general break down and collapse of diseased tissue. Many soil organisms no doubt come in at this point and continue the work of destruction. It is to these latter organisms that we attribute the true rotting found in diseased plants as the primal organism concerned, while effective in killing tissue, is incapable of producing a typical rot such as is usually encountered in diseased specimens which are found in the field.

Physiological Relations.

CULTURAL CHARACTERISTICS.

The fungus grows readily on all of the common laboratory media and on many other media which have been prepared and used in cultural studies. It is easily isolated by the dilution method when pycnidia are present. Single spore colonies appear as thin feathery growths, so characteristic of many of the Fungi Imperfecti. The colonies are at first white; after four to eight days, on certain media, the superficial growth is bluish or bluish-green. The submerged threads are hyaline to black. Acidity, high temperature, and carbohydrates seem to favor color production in the mycelium. Proteins, low temperature, and alkalinity tend to cause little color production. A protein medium also tends to cause permanent loss of potentialities for color production, and for pycnidium production, as well as loss of virulence. Pycnidium production is sparse on all media solidified with agar and on sterile vegetables, with the exception of celery plugs. Ten to twenty days are required for pycnidia to develop. Characteristics of growth on different media are given briefly in a tabular form in the following outline.

TABLE I.—CHARACTERISTICS ON DIFFERENT MEDIA.

Medium	Vegetative Growth	Fruiting
Standard nutrient agar	Growth good, largely superficial, slight mouse colored tinge.	Few pycnidia.
Dextrose agar	Growth abundant, fluffy, largely superficial; tough masses of dark mycelium formed over surface with black sclerotial-like bodies formed in the surface mycelium.	Pycnidia scarce.
Celery agar	Growth good, considerable submerged mycelium; aerial mycelium slightly tinged with blue.	Pycnidia scarce.
Corn meal agar.	Considerable growth below the surface of the substrate; aerial mycelium very faint blue.	Pycnidia sometimes numerous in old cultures.
Oat meal agar.	Mycelium abundant, sometimes filling entire slant in test-tube; black masses of mycelium formed at the edges of cultures.	Pycnidia have been found in old cultures.
Prune juice agar.	Growth moderate, largely aerial, fluffy, white.	No pycnidia were found.
Potato plugs.	Mycelium abundant, compact, white, old cultures form tough black mats	Fruiting not abundant.
Carrot plugs.	Very much the same as with potato plugs; mycelium not so compact and slightly bluish.	Few pycnidia.
Celery plugs.	Growth moderate, fluffy and white at first, later turns blue.	Pycnidia found in great numbers, seated on the surface and visible to the unaided eye.
Beans.	Mycelium very abundant, white or slightly tinged with blue.	No pycnidia observed.
Rice.	Color of rice changed from white to orange color; mycelium varying from light blue to black; growth abundant.	Pycnidia produced in old cultures.
Corn.	Growth moderate, color mycelial mass light blue.	Pycnidia produced in old cultures.
Coons' synthetic. (on filter paper)	Mycelial growth sparse; at first white. later turning dark.	Pycnidia very abundant on both sides of filter paper cone.
Richards' solution.	At first submerged coming to the surface very dense masses formed; color varying from white to black.	No pycnidia observed.

TEMPERATURE RELATIONS.

Vegetative Growth—

The seasons of the year, spring and fall, in which this disease is prevalent, suggest a sharp susceptibility on the part of the fungus to high temperatures. This is forcefully brought to one's attention when he attempts to isolate the organism during a hot period, or attempts to grow it in pure culture at a temperature higher than 27°C. During the summer months it has invariably refused to grow in the laboratory, a fact which has previously been noted by Coons (2). Nearly all the cultural work at such times has been done in a basement where the temperature ranged around 21°C. Where more rapid growth was desired an ice box has been used. This gave a temperature of about 16°C. which is very favorable for vegetative growth.

In the more exact temperature studies with the fungus, a differential thermostat, modeled after that of Ganong's, was employed. At one end of this thermostat there was a cubical container which was filled with ice, and at the opposite end, there was a compartment for water which was heated with an electrical immersion heater. A set of chambers made of galvanized sheet iron connected the two compartments. Between the boiling water at one end, and the ice at the other, there were nine compartments, separated by cardboard partitions. A glass covering was provided to admit light. This gave a range of temperatures which was fairly constant in the middle compartments, but which was somewhat variable near the two extremes.

Using this equipment, preliminary experiments were conducted to determine the effect of temperature on quantity of vegetative growth. Test-tube cultures on agar were first used, then, later, in order to get a giant-colony effect for more exact comparison, these were replaced with Erlenmeyer flasks. Twenty cc. of celery agar were placed in each flask; bits of mycelium of *Phoma apiicola* were placed in the center of the medium and subjected to different temperatures. The experiment, in duplicate, was run for 30 days. The colonies progressed slowly in uniform circles and were actively growing at the time the experiment was concluded. Results in the following table are recorded in terms of average diameter of the colonies. Temperature variations are given as well as the average of twenty readings made during the experiment, values being recorded in terms of the nearest degree.

TABLE 2.—THE EFFECT OF TEMPERATURE ON GROWTH OF MYCELIUM.

Temp. Variation Degrees Centigrade.	Average Temp. Degrees Centigrade.	Average Diameter of Colonies Centimeters.
4– 6	5	.5
8–12	9	1.6
13–15	13	2.5
15–16	16	3.1
18	18	3
20	20	2.8
21–23	22	2.6
25–27	26	1.7
27–30	28	.3
34–40	36	no growth.

These results show that minimum temperature for growth is close to the freezing point of water; maximum temperature is around 28°C. Optimum temperature is somewhere in the range of 16 to 20°C., though very good growth is produced with a few degrees variation either way.

Pycnidium Production—

Quite often pycnidia are not produced on a solid medium and when they do make their appearance it is usually in old cultures where there is great difficulty in making estimates for comparison of response to different treatments.

Cultures of the organism on filter paper, prepared as described by Coons*, are more satisfactory for determining the value of various factors, in pycnidium production. Fruiting bodies have been found to be formed in greater numbers and results are more easily and accurately estimated. This method consists, essentially, in placing filter paper cones in a deep culture dish with the addition of a liquid medium. The nutrient solution used has been either cornmeal broth or Coons' synthetic solution. Either is very satisfactory although the latter gives a greater mycelial development and a larger number of pycnidia.

Four deep culture dishes, prepared as outlined above, were inoculated with mycelium of *Phoma apiicola* and placed in each compartment of the differential thermostat. They were allowed to remain thirty days. During this period, the temperature in the basement in which the test was conducted, was fortunately very constant. Therefore, the temperature in the different compartments varied little, after the first two days. The temperatures given below are averages for the period; except in the case of the last two figures the variation was not more than one degree in either direction.

TABLE 3.—THE EFFECT OF TEMPERATURE ON PYCNIDIUM FORMATION.

Average Temp. Degrees Centigrade.	Relative Mycelial Growth.	Pycnidia.
4	75	—
10	80	—
13	90	+
16	100	+
18	100	+
20	80	+
23	40	+
26 (±1)	10	+
35 (±1)	No Growth.	

The quantity of mycelium produced at different temperatures is in harmony with previous experiments. Color reactions on different media have been noted before, but they came in here in a very pronounced form in response to heat. At 4° and 10°, the mycelium was almost white. As the temperature increased, the color became more intense. At 26° there was very little vegetative growth, but that which was produced had a very intense, dark bluish cast.

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* Coons, G. H. Factors involved in the growth and pycnidium formation of Plenodomus fuscomaculans. Jour. Agr. Res. 5:713-769. 1916.

Pycnidia began to appear at the end of 14 days. Larger number of fruiting bodies were produced at 13°, 16° and 18°, though, per unit of mycelium, there were as many produced at 26° as at any other temperature.

At 4° and 10°, while there was a very good mycelial growth, there were no pycnidia; however, after these cultures were removed and placed at 21° the characteristic bluish color came in and pycnidia were produced as abundantly as in any of the other cultures.

High temperature seems to lessen pycnidium production only as it lessens mycelial growth. Low temperature, i. e. below 10°, represses pycnidium production, but a short exposure does not destroy the potentialities for fruiting.

Germination of Spores—

In moist chambers and liquid culture, the spores of *Phoma apiicola* have been very slow in germinating. From 36 to 48 hours have been required for the first indications of germination at room temperature. After the mycelium had shown such a marked response to relatively high temperature, it was suspected that spores were being kept at too high a temperature for the most rapid germination. Pycnidia from deep culture dishes were crushed and the spores placed in small test-tubes containing sterile tap water. These were incubated, four tubes being placed at each temperature recorded below. Loops from these tubes were examined every 12 hours for germination of spores. Results are given in the following table.

TABLE 4.—EFFECT OF TEMPERATURE ON GERMINATION OF SPORES.

Temperature Degrees Centigrade.	Stage of Germination.			
	24 hrs.	48 hrs.	60 hrs.	84 hrs.
4	....	....	swelling	budding
10	....	....	swelling	germ tube
13	....	budding	germ tube	germ tube
16	swelling	germ tube	germ tube	germ tube
18	swelling	germ tube	germ tube	germ tube
20	....	swelling	germ tube	germ tube
23	....	swelling	budding	germ tube
26	....	....	....	swelling

At least 24 hours are required for germination at any temperature. The most favorable temperature for vegetative growth, 16° to 18°, is also conducive to most rapid spore germination. As indicated by the weak germination at 4°, the minimum is very little below that temperature. Maximum temperature is close to 26°.

The most outstanding feature is the length of time required for germination even at the most favorable temperature. In this, we probably have a decisive factor making for restriction of the fungus to the underground parts of the host plant under field conditions. The spores, as indicated by inoculation and germination experiments, require considerable moisture for germination. Under weather conditions which prevail in the celery growing districts of Michigan, a fungus restricted by such moisture requirements must necessarily have a spore which will germinate and produce infection in a short time, if it is to become an important leaf spotting organism. The spores of the root rot organism under natural conditions do not ordinarily produce infection on the above-ground parts because of the drying out of the leaves and the leaf petioles before the germ tubes have had time to form and penetrate the host tissue.

Thermal Death-Point—

The ability of the fungus mycelium to withstand low temperatures has been tested by placing flask cultures outside of a window when the out-door temperature ranged from −18° to −28°C. Transfers proved that the mycelium was not killed after several days' exposure.

In the higher range of temperatures the mycelium is killed by subjecting it to 35° for a period of 72 hours. A ten-day exposure at 32° stopped growth but was not sufficient to produce death. Shorter exposures at lower temperatures indicate that the thermal death-point of the mycelium is very close to that of the spores which at a 10-minute exposure are killed at 49°.

In determining the thermal death-point of spores the capillary tube method, as described by Novy*, has been used. Capillary tubes, five inches in length and about 2mm. in cross section, were drawn out from a piece of thin-walled glass tubing. These were inserted in a spore suspension until they were properly filled, then sealed at each end. The tubes were immersed in water baths held at constant temperatures. At the end of the time of treatment they were cooled in water at a temperature of about 21°C. The tip of one end was then broken off, using aseptic precautions, and the contents discharged into melted agar by applying heat to the unbroken end. The experiment was run twice in duplicate, first with an interval of 5 degrees and later with an interval of 1 degree. Results are combined in the following table:

TABLE 5.—THERMAL DEATH-POINT OF SPORES.

Temperature Degrees Centigrade.	Germination of Spores. Time of Exposures in Minutes.			
	5	10	20	60
35	+	+	+	+
40	+	+	+	+
45	+	+	+	−
46		+		
47		+		
48		+		
49		−		
50	−	−	−	−

The thermal death-point of spores, at an exposure of 10 minutes, lies between 48 and 49 degrees. Only a few spores germinated at 48 degrees, indicating that there was some slight variation in the treatment which the spores in any one tube received or that some of the spores had slightly greater potentialities for withstanding heat than did others.

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* Novy, F. G. Laboratory work in Bacteriology. 1899. Ann Arbor Mich. (George Wahr.)

LIGHT RELATIONS.

Physiological investigations in this field have indicated that, with many species of higher fungi, light is of little importance either as a stimulant or as a repressant of vegetative growth. With many of these same organisms, however, light is an important and often an essential factor in spore production. Levin*, working with a number of species of Sphaeropsidales found that while mycelial growth was just as abundant, fruiting was considerably lessened and, in several species, completely suppressed by absence of light. Species of Coniothyrium, Phyllosticta and Cytospora showed considerable pycnidium production in the dark but at that suffered a falling off of more than 55 per cent when light was excluded. Species of Ascochyta, Phoma, Sphaeropsis, and Fusicoccum produced no pycnidia in the dark. Coons† has found that, in the case of *Plenodomus fuscomaculans,* darkness has little or no effect on vegetative growth, but is prohibitive to pycnidium production.

With these results in mind, experiments were planned to determine the effect of light and darkness in vegetative growth and pycnidium production in the case of *Phoma apiicola.* To provide for darkness and at the same time allow for the circulation of air, a method modeled after that of Coons was used. To exclude light, two battery jars were wrapped in heavy black paper. The larger was placed bottom end up over the smaller one and allowed to rest on a block of wood, thus providing for a passage of air at the base and over the top of the jar within. A similar arrangement was prepared, using heavy wrapping paper, for obtaining diffused light. Two jars without any covering were used in the series exposed to light. Filter paper cones were placed in preparation dishes (5 cm. diam.) containing 5cc. of corn meal broth as the nutrient medium. Inoculations were made directly from mycelium. Eight dishes were placed in each jar. Results are tabulated below.

TABLE 6.—EFFECT OF LIGHT ON GROWTH AND PYCNIDIUM PRODUCTION.

Treatment.	Percentage Development, Based on Best Culture.	
	Pycnidia.	Mycelium.
Light	100	90
Diffused Light	80	100
Dark	80	90

Pycnidia were produced in greater numbers in light than under any other conditions. It is conclusively demonstrated, however, that light is not an essential factor in the fruiting of this organism. Light seems to stimulate fruit body production, probably due to the lessening of vegetative growth or to some other indirect action.

Greatest mycelial development was obtained in diffused light, here also the hyphae were more upright producing a looser and more fluffy mass. In darkness there was apparently as much growth as in strong diffused light.

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* Levin, Ezra. Light and pycnidia formation in the Sphaeropsidales. Report Mich. Acad. Sci. 17:134-135. 1915.

† Coons, G. H. Factors involved in the growth and pycnidium formation of Planodomus fuscomaculans, Jour. Agr. Res. 5:713-769. 1916.

Under normal conditions on the host the organism is not subjected to strong light when it grows around the base of the plants just beneath the surface of the soil. Long continued growth under such conditions may have produced a physiological adaptation to environmental conditions. At any rate it is a significant fact that the light relations which are most favorable for development in culture are those to which the fungus is subjected when functioning as a pathogenic organism.

RELATION TO DESICCATION.

Mycelium of this organism will live for a period of two or three months when grown on an artificial medium and allowed to dry. Longevity varies with the character of the growth on the different media; rice, which produces thick tough mats of growth and hyphae with thick walled cells, is conducive to great resistance; soil and certain synthetic media produce a more delicate type of growth which succumbs more readily to desiccation. The organism was grown on sterile muck until the soil was thoroughly filled with a loose growth of mycelium. Samples of this were removed, placed in sterile filter paper and subjected to drying at room temperature. Plating brought out the fact that the mycelium under these conditions was not living at the end of 35 days but was still capable of producing growth at the end of 28 days.

With many organisms, it is unquestionably true that longevity of spores subjected to drying on glass surfaces furnishes no reliable index as to their persistence in nature. The longevity of fungus spores as well as of bacteria depends largely on the medium upon which they are subjected to drying and also on whether or not they are imbedded in a gelatinous matrix.

Spores of *Phoma apiicola* were tested in the usual manner by drying them on cover glasses and then testing their viability by placing them in broth. Under these conditions 60 hours was the longest period that spores withstood desiccation. Other methods have been employed to more nearly approach some of the conditions to which spores might be subjected in nature. Celery seeds were treated with mercuric bichloride, thoroughly washed, inoculated with spores and subjected to drying on sterile filter paper. The seeds were placed in broth at regular intervals. Spores germinated after 38 days desiccation; above this, the limit of resistance seemed to be reached and no more germination was obtained. To eliminate any inhibiting or germicidal effect, which might be produced by traces of mercuric bichloride untreated seeds were inoculated with spores, divided into two lots and subjected to drying. Platings were made from the first lot while seeds from the second lot were planted in pots at the end of every seventh day. Platings gave, substantially, the same results as obtained in previous experiments. In the first three plantings of seeds, infection was produced in the seedlings; the fourth planting gave negative results, and subsequent plantings failed to produce infection in the seedlings.

These results merely indicate that free spores exposed on the surface of celery seeds, are not able to survive desiccation at room temperature for a period longer than 30 days. Because of the many varying factors, these tests cannot be taken as an accurate index as to the time which must elapse, before infected seeds may be considered safe. Spores used in the above experiments were produced in pure culture. Under such conditions, there is always the possibility of the spores being less resistant than those produced on the host plant. Under natural conditions, the spores discharged are imbedded in a gelatinous matrix which would serve to make them more resistant to adverse conditions of environment. When we consider these differences and the fact that pycnidia also may be produced on the seeds, (Klebahn) possibly existing there as immature fruiting bodies capable of later producing spores, it seems extremely likely that, while ordinary conditions of desiccation may be important in killing large numbers of superficial spores, there is not enough evidence to conclude that desiccation is effective in entirely freeing seeds from the living organism.

OXYGEN RELATIONS.

The seat of this disease is near the surface of the soil regardless of whether leaf stalks, crowns, or roots are located at that place. Light is evidently not an important factor in this restriction. Experiments early indicated that the organism is an aerobe. Inoculation to Giltner* H-tubes produced no growth. Broth cultures covered with paraffin oil showed the same results. Very little growth was produced on oatmeal agar in test-tubes when the tops were sealed with paraffin though the volume of air, in such cases, was many times that of the fungus. In tubes of sterile muck, the depth to which the fungus penetrates can be regulated by changing the compactness of the soil. In very loose muck, the fungus seldom penetrates deeper than an inch and a half; in more compact or water logged soil the growth is largely superficial. The same observation has been made in flasks where, in order to get thorough penetration, it is necessary to have the proper amount of moisture and to aerate the soil by shaking the flasks at frequent intervals.

To determine the effect of introducing large supplies of oxygen, an experiment was set up in the following manner: Potted plants, having a well established root system, were allowed to dry to the wilting point. They were then taken from the pots, none of the soil around the roots being disturbed, and soaked in water, having a heavy charge of spores. After being placed in 6-inch battery jars and well tamped in with more soil, the entire mass was then drenched with a spore suspension. Glass tubes, bent into a hook so as to deliver air currents upward, were placed in the bottom of the jars and connected with a compressed air reservoir. The amount of air admitted was determined by allowing the air to bubble through water in a wash bottle. An average of about 120 bubbles per minute was introduced for a period of two months. Checks were run where no oxygen was supplied and also where no inoculation was made. When a difference in the size of tops, between the plants supplied with oxygen and the checks, became noticeable, the plants were removed, washed, and examined for signs of disease. Plate VI, Fig 2, shows a picture of a typical plant supplied with oxygen. The roots were attacked at many different points and many of these rotted off two or three inches from the crown; smaller roots had suffered severely and the whole root system was in an advanced stage of decay. The presence of hundreds of pycnidia scattered over the root system furnishes proof of the organism causing the destruction. On the inoculated check plants, the disease was produced only around the crown; the roots were as thrifty and as free from disease as in the case of the uninoculated plants.

This air relation, we believe, explains why a large part of the disease on the roots is near the crown and why roots deep in the soil are very rarely attacked. Excessively high moisture content in the soil, since it drives out the air and makes less oxygen available, would tend to still further restrict the susceptible area, though relatively wet conditions are requisite for mycelial proliferation. As has been shown, lack of sufficient moisture in the air in nearly all of the celery growing districts in Michigan where the fungus is known keeps it from the aerial parts. Thus, the physiological relations of the fungus to these two environmental factors, namely water and air supply, determined the type of disease which is produced, and the part of the host plant which is dangerously subject to attack.

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*Giltner, W. Laboratory Manual in General Microbiology. pp. 160-162. New York, 1916.

RELATION TO THE REACTION OF THE MEDIUM.

Several different media have been used in determining the relation of acidity and alkalinity to the growth of *Phoma apiicola*. Celery agar, nutrient broth, and Coons' synthetic solutions have been employed in several experiments.

With the solid media used, a neutral or slightly acid reaction is most favorable for growth. The same is true of the liquid media used but the initial reaction for production of the greatest amount of growth varies with the chemical composition of the medium. This can be brought out more clearly by a description of a typical experiment. Flasks of nutrient broth were prepared to range in reaction from pH. 2 to pH. 9.6 by adding N/20 hydrochloric acid or N/20 sodium hydroxide until the desired reaction was obtained. Each flask was inoculated with a small bit of mycelium and incubated at room temperature. In the following table, results are given for different periods of time on a percentage basis, reckoning the flask showing best growth as 100 per cent.

TABLE 7.—EFFECT OF ACIDITY AND ALKALINITY ON MYCELIAL GROWTH.

Reaction.	Estimated percentage development based on flask showing largest mycelial mass.		
	2 weeks.	4 weeks.	8 weeks.
pH 9.0	...	...	...
pH 8.5	5	5	...
pH 8.0	10	10	5
pH 7.5	25	20	10
pH 7.0	90	75	60
pH 6.5	100	80	70
pH 6.0	90	90	80
pH 5.5	60	100	90
pH 5.0	40	70	100
pH 4.5	25	25	50
pH 4.0	5	5	5

At the beginning, there was a much more rapid growth at the neutral point. As development continued, those flasks having an initial reaction of pH. 6.5, 6.0 and 5.5 respectively replaced the neutral flasks in quantity of mycelium produced. This came about both through a gradual acceleration of rate of growth in the acid and a slowing up in the alkaline media. Flasks, neutral and alkaline, had practically ceased growth at the end of four weeks. In those having an acid reaction, the fungus continued a fair rate of growth up to the end of the eighth week. The slowness of growth in the acid flasks at the beginning was no doubt due to an unfavorable reaction, the longer period of growth being made possible through the breaking down of protein molecules into alkaline compounds. This decomposition, brought about through the activities of the fungus, had the effect of making the reaction of the medium increasingly more favorable for growth up to the point at which the alkaline compounds began to exert a deleterious influence, and then, of slowing up growth until the medium became too toxic for further development. Thus, in a single flask, the organism was able to pass from the limits of acid tolerance on the one hand to an alkaline solution on the other. Various toxic substances thrown off by the fungus were no doubt important in stopping growth before the outer limits of alkaline tolerance were reached, since pH. determinations at the end of the experiment proved that the flasks having an acid reaction at the start were only slightly alkaline. Inoculated flasks of broth, having an initial reaction of pH. 5.5, showed a gradual change in reaction up until the end of the eighth week, when they had a reaction of pH. 8.2.

A series of deep culture dishes, with Coons' synthetic solution as the nutrient medium, were inoculated to determine the effect of reaction of the medium on pycnidium production.

TABLE 8.

Reaction of Medium H-ion concentration.	Comparative development based on greatest number of pycnidia and largest mass of mycelium.	
	Pycnidia.	Mycelium.
9.0	5	5
8.0	50	75
7.0	80	100
6.0	100	85
5.0	0	slight
4.0	0	slight

The limits of fruiting seem to be as wide as those for mycelial development. The neutral medium again markedly favored vegetative growth, while solutions slightly acid brought forth the largest number of pycnidia. The salient feature in these results is the failure of the solutions acid to pH. 5.0 to produce growth in measurable quantities. At first glance, this seems contradictory to results obtained in broth cultures. The solution used in this experiment, however, has more carbohydrate and less protein in its composition than has beef broth. The probability is, that, on account of the nature of the medium, the fungus was unable to adjust the reaction in its favor and that pH. 5.0 is too acid for growth.

The cultures at different reactions produced a noticeable series of color changes, though there is not such a wide variation as is produced in the case of extreme temperatures. In the alkaline solutions, the fungus produced a pink discoloration, which is never observed in neutral or acid solutions, and the color of the mycelium varied from an almost white to a light blue color. The acid solution produced a bluish or bluish-green mycelium.

Dissemination.

The restriction of the pycnidia of the causal organism to the roots and crown of the host plant makes air currents of little importance in the dissemination of the disease. The gelatinous matrix in which the spores are imbedded necessitates a water distribution. When pycnidia are mature and the spores pushed out in long tendril-like threads, the jelly-like matrix is dissolved away leaving the spores free to be washed through the soil.

The importance of this method of dissemination will depend largely on the frequency of heavy rains and on the amount of surface drainage. When the disease is present in the seed bed spores are disseminated by handling plants at transplanting time. It is quite a common practice to take plants from the seed bed and place the roots in water in a shallow pan until they can be placed in rows in the field. Under such conditions a single diseased plant, bearing pycnidia of the pathogen, would be capable of infecting an enormous number of sound individuals.

With an organism capable of living and growing for a period in soil, the question of lateral dissemination by means of the growth of mycelium through the soil must be considered. To gather experimental evidence on this point plants in one side in each of five average size flats were inoculated in the greenhouse and checks placed in the same flats at a distance of 4 to 12 inches from inoculated plants. Watering was done with a sprinkler and the soil was kept moist enough for a good growth of celery. After three months the plants were pulled up and washed free from soil. Of the inoculated plants 96 per cent were diseased; 2 per cent of the plants four inches from inoculated plants were attacked, and all other uninoculated plants were free from disease. Pot experiments and observations on checks used in the greater part of greenhouse work have confirmed these results. It might be pointed out that in the above experiments conditions were very favorable for spread of mycelium as the soil was kept damp at all times. Due to its oxygen relation the fungus can penetrate soil only to a short depth, and since in the field surface soil is often dry the spread from plant to plant by means of mycelium will assume even less importance than in the greenhouse.

Varietal Susceptibility.

The whole question of varietal susceptibility is one which will require more searching investigation and critical observation to solve the problems here presented. Van Hook reports that Giant Pascal and Evans' Triumph are much freer from the disease than is Golden Self Blanching. The most destructive outbreaks of the disease in Michigan have been on Golden Self Blanching celery, but unfortunately in these cases, no other varieties have been present in the infested districts on which to make observations, or with which to make comparisons. White Plume and Easy Bleaching are known to be subject to attack under field conditions; other varieties have such a limited use that data as to their relative resistance are not available. The results obtained from the inoculation of a limited number of various plants of various varieties, permit some decision in this regard.

A variety test was conducted using Perle Le Grand, Smallage, Schumacker, Dreer's Mammoth, Perfection, Easy Bleaching, Heartwell, Dwarf Golden Heart, Winter Queen, Rose Ribbed Paris, Golden Self Blanching, Boston Market, Columbia and Golden Heart. The method adopted for testing these varieties was to place twenty-five plants of each variety in a separate flat and thoroughly spray them with spores.

Indications of infection first become apparent on Golden Self Blanching and Golden Heart plants through a dying of the lower leaves and a general checking of growth. In time, the same symptoms were to be noted on all other varieties except White Plume and Giant Pascal. All inoculated plants of these two varieties, upon examination, proved to be diseased; but the characteristic symptoms were not to be seen on the parts of the plants above ground. At the base, a thin ring of black diseased tissue showed that the fungus was active, but was not seriously interfering with growth. In the case of the other varieties there seemed to be no great difference in susceptibility.

As a result of these tests we feel justified in saying that though none of the common varieties are immune to this disease, some give indication of being more resistant than others. Golden Heart, Golden Self Blanching and Dwarf Golden Heart, seem to be the three varieties which suffer most from the disease. White Plume, Giant Pascal, and Easy Bleaching give indication of being more resistant. These last three varieties are large, rapid growing plants of a tougher texture. Herein probably lies the secret of resistance. Succulent plants of any variety are more susceptible than plants of a tougher texture. Similarly different species of Umbelliferae seem to correlate resistance with woodiness.

Life History of the Casual Organism.

In tracing the detailed life history of the parasite in relation to diseased production, it is well first to consider the periodical development of the disease in the greenhouse and under field conditions. The first plant infection quite often came in the greenhouse or in the out-door seed bed in the early spring. Clean plants of the first crop may be attacked after they are transplanted to the field. The second crop or celery growing during midsummer is usually free from serious attacks. As the cool days of fall come on, the Phoma root rot fungus again becomes active and may produce serious damage in the last crop.

There are several possible ways in which the causal organisms may pass the winter; (1) in soil or trash of the greenhouse or in the cold frame; (2) the refuse of the previous year's crop in the field; (3) as a saprophyte in the soil; (4) on seeds, and (5) of course, there is always a possibility, with an organism of this type, that there is an undiscovered perfect stage produced. As to the first possibility the fungus is known to persist through one season under such conditions. In case of the most serious outbreaks of the disease at Kalamazoo, Michigan, the greenhouse was the location where infection took place during two successive years and the point from which the disease was carried to the field. The source of the organism for the initial infection is unknown, but the appearance of the disease in a very virulent form the second year points strongly to the fungus having lived over in the soil or trash of the seed bed. In the greenhouse at the Michigan Agricultural College, plants became diseased when placed in soil from around diseased plants, after this soil had been kept in flats in the greenhouse through the winter up to February.

There has been some difference of opinion regarding the importance of trash in harboring the organism. Klebahn is inclined to the belief that seeds are very important in the distribution of this disease, while Quanjer and Slagter minimize seed carriage and state that the chief source of infection is to be found in the trash, manure, etc. To determine something of the importance of trash and also to determine whether or not the organism lived as a saprophyte in the soil through the winter an experiment was started September, 1919 on the following basis. Seven large flats were placed out of doors over winter. Two of these contained growing plants which had been inoculated in midsummer and which were known to be diseased, in two others were diseased plants pulled from the soil and left on the surface; two contained muck soil, mixed with sterile muck on which the fungus was growing. In one flat diseased bases of plants were placed between layers of thick filter paper and covered with soil to depths varying from 1 to 6 inches. April 1, 1920, the first six flats were taken into the greenhouse and planted to celery. By May 1, the plants in the four flats containing trash were showing signs of disease. The two flats containing soil inoculated with a pure culture of the pathogen did not produce the disease, indicating that under the conditions of the experiment the fungus did not persist in the soil as a saprophyte. The diseased parts in the remaining flat were examined for pycnidia and for a possible perfect stage. The latter quest was wholly unsuccessful, but pycnidia containing an abundance of spores were found on nearly all diseased parts. These spores germinated readily in tap water and indeed many of them had apparently germinated between the layers of filter paper as masses of bluish mycelium were everywhere present. This mycelium, after isolation, corresponded to that of *Phoma apiicola* and produced disease when placed in contact with celery plants.

Before 1914 the greater portion of the celery seeds used in the United States was grown in Holland and France, where this disease is most destructive. As such seed importation is likely to regain its former volume, it is a question of first importance to determine whether or not the causal organism is seed borne.

Klebahn (5) found pycnidia of *Phoma apiicola* on the seeds and suggests that seed distribution is important. Quanjer and Slagter (6) as stated before incline to the belief that infection from the seeds is exceptional.

This latter view seems to fit in well with the facts as observed in Michigan. The disease has, no doubt, been introduced from Europe on the seed or on trash present with the seeds, but the occurrence of the fungus on seeds is probably rare. Examination of French, English, and Dutch grown seeds has not shown pycnidia to be present. The infrequency with which the disease is found in the seed bed indicates that in the case of seeds shipped to America from infested European countries introduction with the seed does not commonly occur. While not often carried on the seeds, sporadic outbreaks of the disease in one or two instances indicate that the seeds in some cases may have been heavily infested. It is probable that seed carriage is important in introducing the disease into new territories and in occasionally being the source of bad seedling infections, but as a means of annual distribution of the disease, it is probably of minor importance.

CONTROL.

Because of the fact that plants are attacked at a point located below the surface of the soil, none of our common sprays which are used to fight other diseases of the celery plant are effective against this disease. Control measures must be based largely on certain relations of the disease to environmental conditions and on the application of sanitary measures. In applying such methods it is well to keep the following points in mind: (1) While some varieties of celery are more or less resistant, none are known to be wholly immune; (2) the disease may occasionally be seed borne; (3) low temperature and high moisture content in the soil favor the production of disease;

(4) attacks are most severe in the spring and fall; (5) greatest injury comes from attacks on small plants; (6) older plants are not so seriously affected; (7) trash of the greenhouse and field are important sources of infectious material.

It is out of the question to rely on any of our common varieties to resist the attacks of the fungus. The varieties of best quality seem to be most susceptible to the disease, and some of the varieties of poorest quality seem to be slightly resistant, but not enough difference has been found to justify the grower in sacrificing quality for resistance.

The possibility of the disease being seed borne leads to the question of seed treatment and sources of contaminated seeds. Phoma root rot has not been reported from any seed producing section of the United States. If it is present in any of these districts it is evidently causing little damage and chances of seed infection would be very small. European grown seeds are more apt to carry infection and treatment of such seeds may prove to be a good insurance measure against introduction of the disease into the seed-bed.

A low temperature, combined with a high moisture content in the soil, is necessary if the disease is to become of economic importance. In seedbeds where conditions can be controlled as in the greenhouse, we believe that it would be possible to check the disease and in many cases prevent infection by limiting the water supply and keeping the temperature relatively high; but, since the seedling stage is the critical one for infection, it is dangerous to rely on this treatment. If seedlings of the first crop are kept free from infection until they are transplanted to the field, it is believed that in an average year the disease, caused by infection from field sources, is not capable of producing a great amount of destruction before its progress is arrested by the warm weather of summer. It is far safer to keep watch of the seed bed and if the disease appears, to change or to sterilize the soil before another crop of plants is grown.

In the greenhouse it is possible that the fungus may persist for a considerable time in the partially rotted wood of benches and in other decaying material. For this reason all parts which have been in contact with infested soil should be drenched with some good disinfectant before disease-free soil is brought from the outside. A solution of formaldehyde diluted to one part formaldehyde to forty of water has been found to be very effective in killing spores and mycelium of the causal organism when this fungus has been grown in sterile muck. Drenching infested soil with the same strength of solution would no doubt prove effective in destroying the fungus in seed beds under natural conditions.

In the case of the fall crop, field infection may be a source of considerable loss. In dealing with this, it may be necessary to practice rotation and to remove all diseased trash from the crops of celery which are grown in the rotation. Under field conditions it is not known how long the causal organism may persist in the soil and trash, but the removal of diseased parts from the field should decrease considerably the amount of infection. Crop rotation would seem to be a very effective method of control in sections where land is available and celery can be replaced by crops equally valuable. In districts where rotation is not practiced it is believed that the removal of diseased trash and the use of disease-free plants as mentioned above, will hold the disease in check and insure the grower a crop comparatively free from this type of root rot.

SUMMARY.

Phoma Root Rot is a disease of celery and celeriac known both in Europe and America and is caused by the same fungus (*Phoma apiicola*) in both cases.

The fungus also attacks parsley (*Carum petroselinum*), parsnip (*Pastinaca sativa*), carrot (*Daucus carota*), and caraway (*Carum carvi*).

The disease comes in on the crown of plants and causes dead leaves at the base, ''stunting'', and a pinching off near the surface of the soil.

The causal organism requires a relatively low temperature (optimum about 18°C.) and abundance of moisture and a large supply of oxygen for best growth.

The disease reaches its maximum of destructiveness in the spring and fall, the hot weather of midsummer checks the advance of the fungus and gives a crop free from its attack.

Over-wintering is known to take place in the trash of the field.

Control measures recommended are the use of disease-free plants and the destruction of trash which harbors the pathogen, or when the disease is severe, the rotation of crops.

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* This bibliography contains only those references which bear directly on the disease in question other references are given in the foot notes.

Plate I Michigan Technical Bulletin No. 53

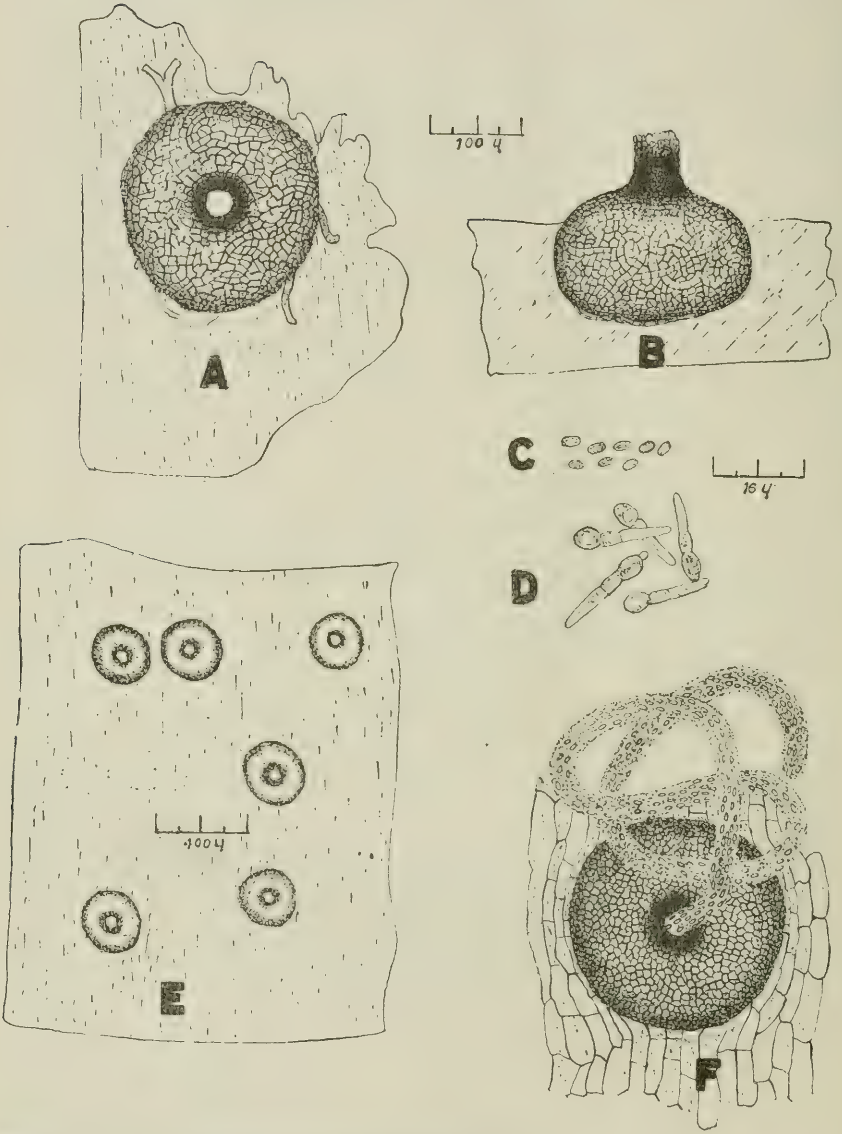


Plate **I.** (a) Pycnidium showing ostiole.
(b) Pycnidium showing neck.
(c) Spores.
(d) Germinating spores.
(e) Group of pycnidia as the appear on the host plant.
(f) Pycnidium showing discharge of spores.

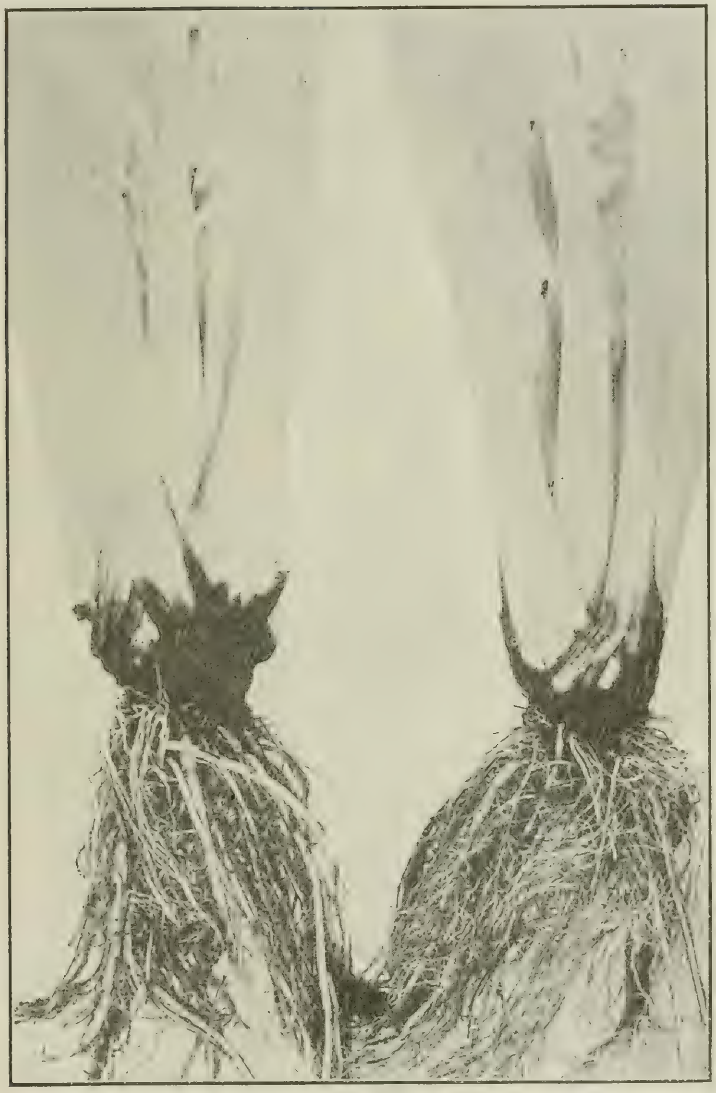


Plate II. Diseased plants as they appear before all the roots are rotted away.

Plate III.

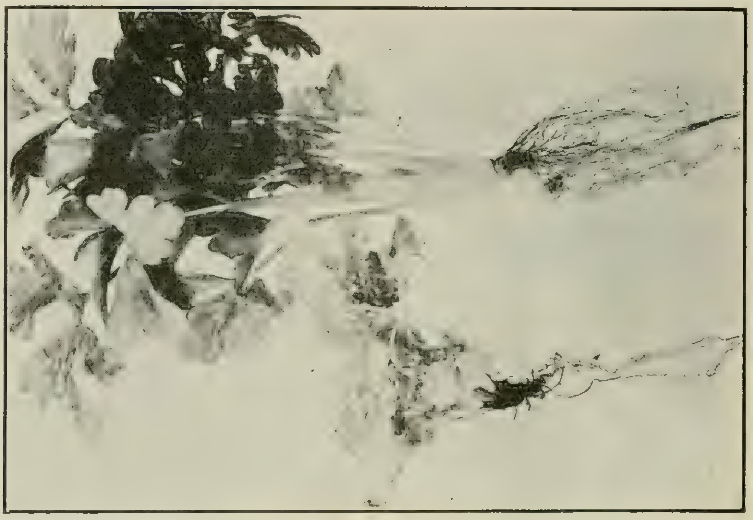


Fig. 2.

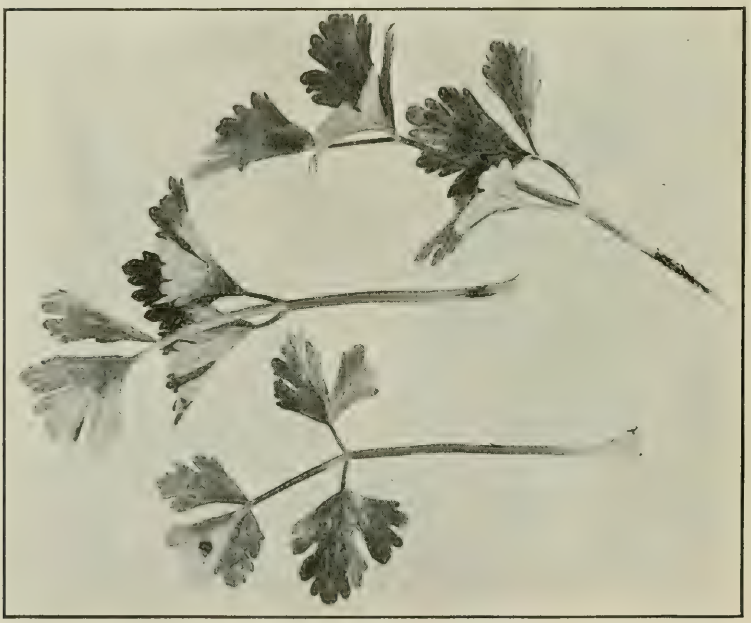


Fig. 1.

Plate III. Fig. 1. Infection on leaflets (upper left) and on leaf petioles. (Photograph and inoculation by Dr. G. H. Coons.)
Fig. 2. Diseased (left) and healthy (right) plants of the same age. (½ nat. size.)

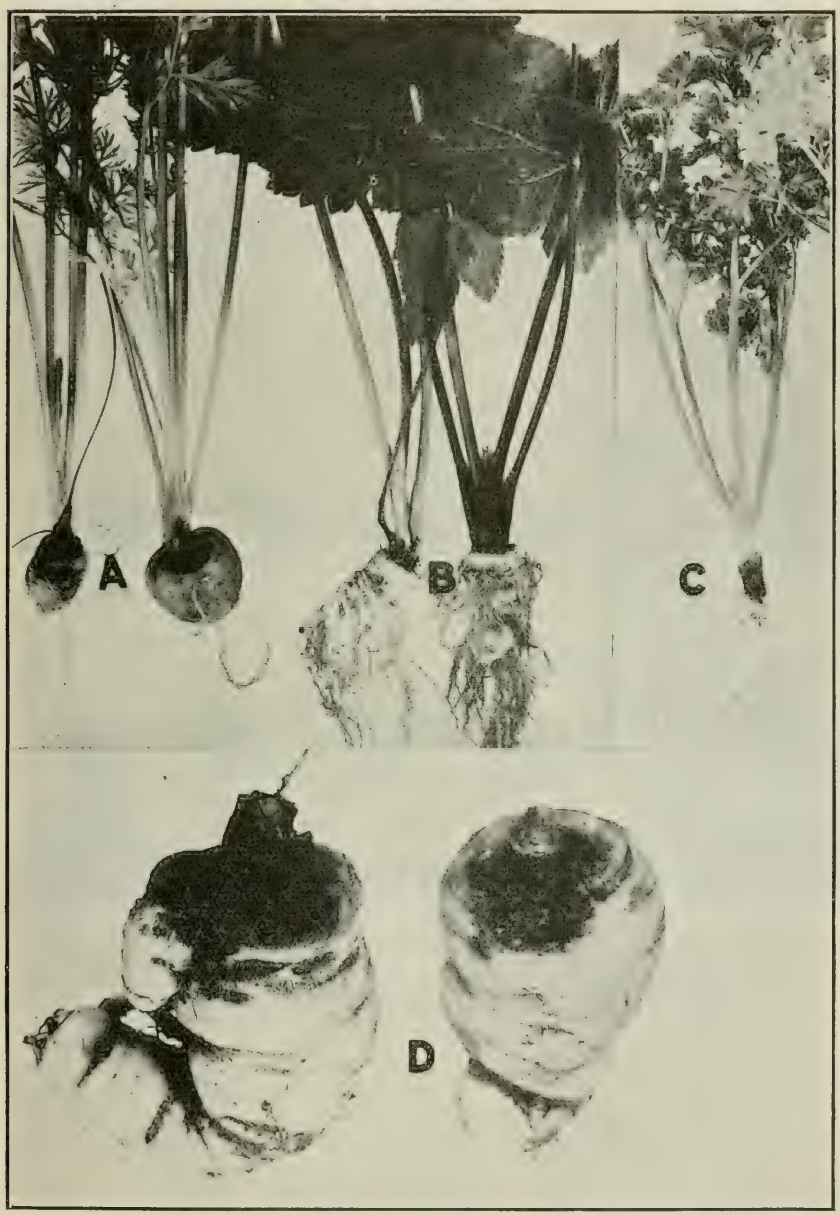


Plate IV. Phoma rot on (a) carrot, (b) parsnip, (c) parsley, and (d) parsnip.

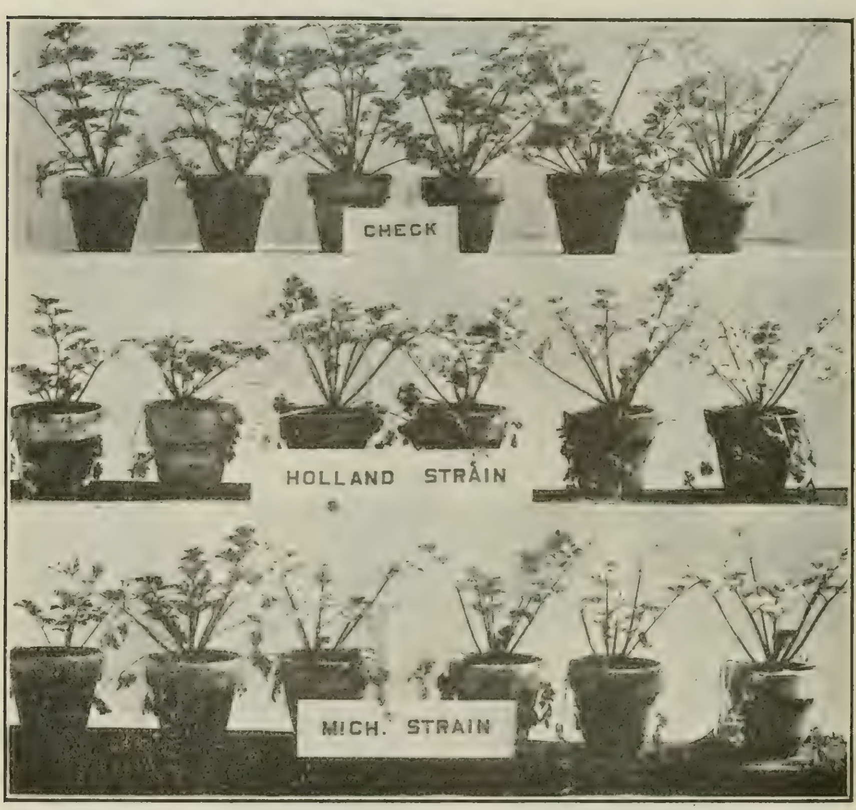
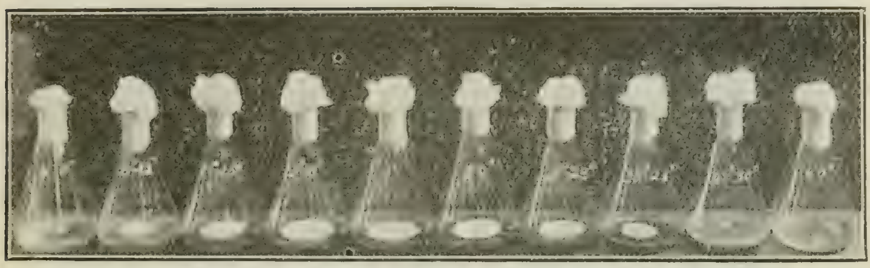


Plate V. Plants 4 weeks after inoculation, showing the typical drooping and killing of the outer leaves. Holland and Michigan strains of *Phoma apiicola* on Easy Bleaching celery.



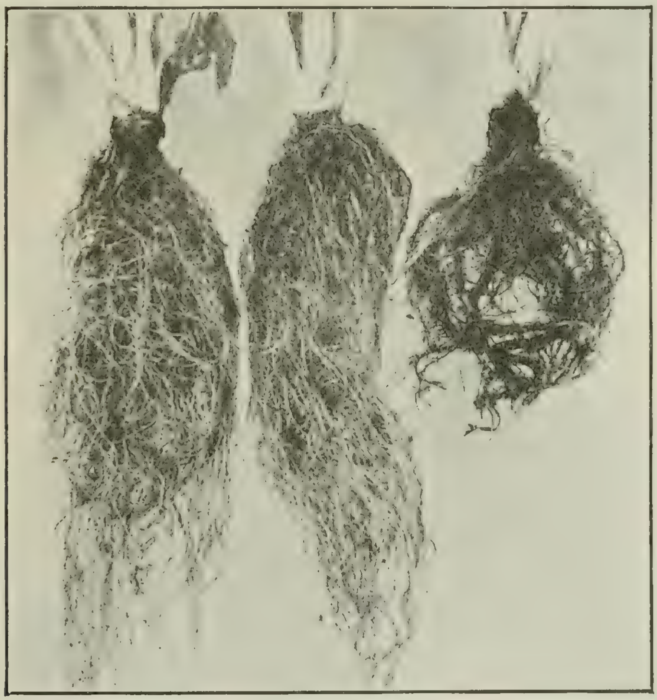


Plate VI. Fig. 1. (Top) Showing the relation of temperature to mycelial growth.

Fig. 2. The effect of air on root attacks. The plant at the left was not inoculated; the middle one was inoculated and supplied no air; the plant on the right was inoculated supplied air. Note the scarcity of smaller roots and the diseased condition of the larger ones.

Plate VII Michigan Technical Bulletin No. 53

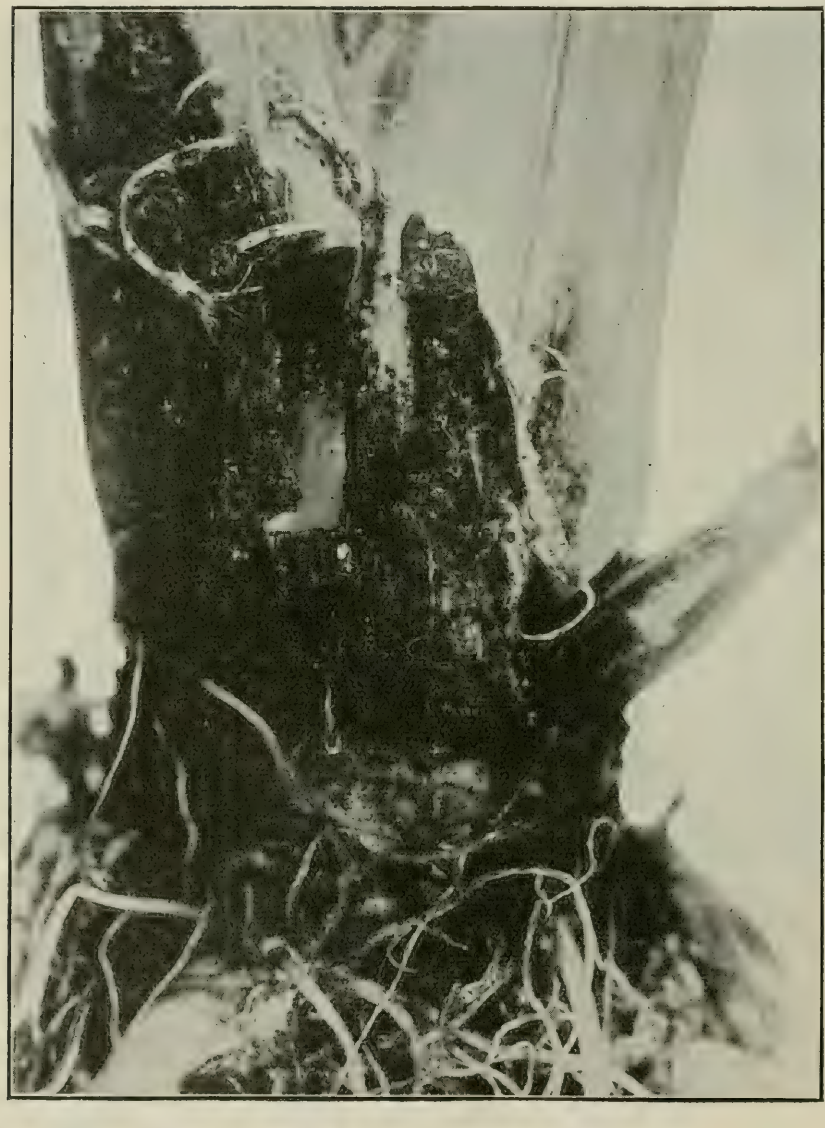
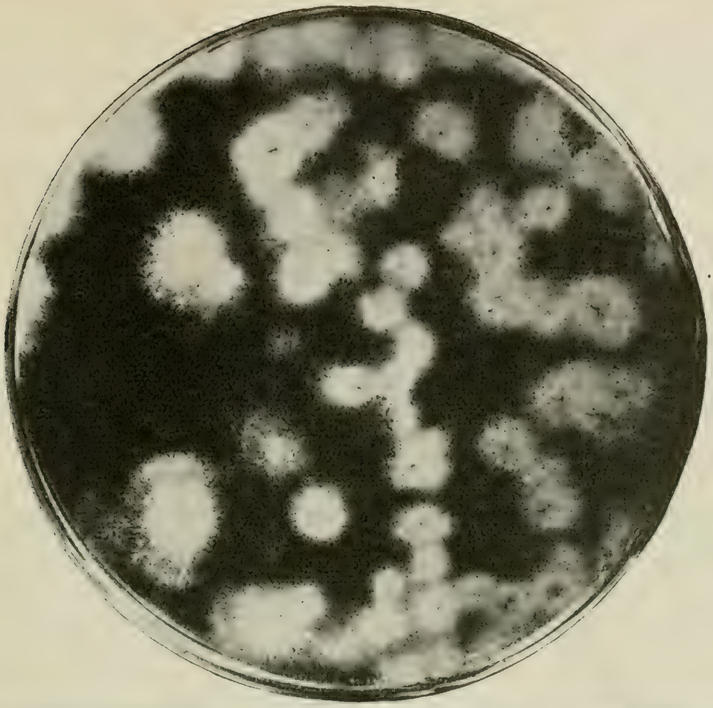


Plate VII. Diseased base of plant showing pycnidia.
(Enlarged 6 times.)



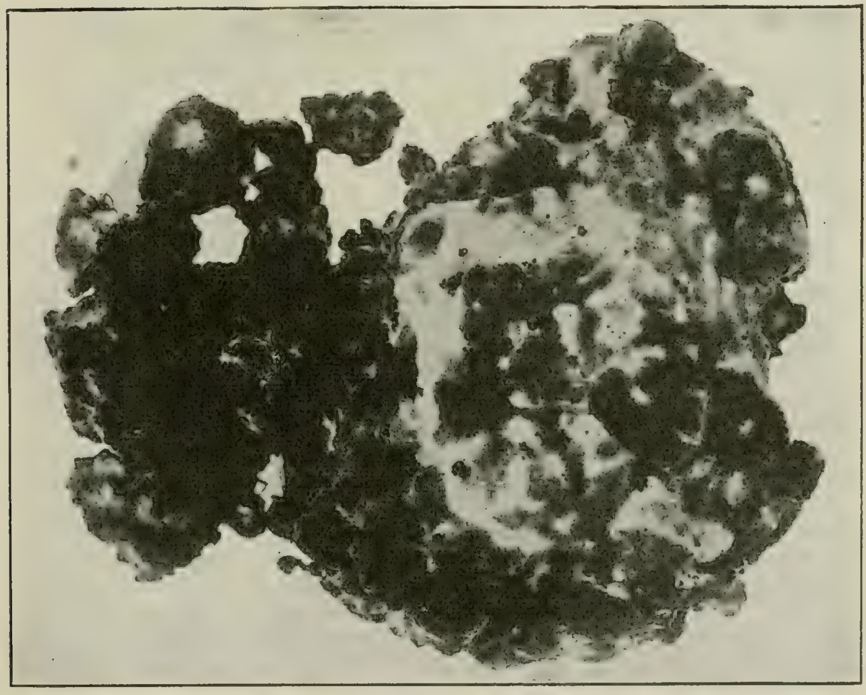


Plate VIII. Fig. 1. (Top) Culture showing type of growth produced on cornmeal agar.

Fig. 2. Mycelium of *Phoma apiicola* on muck soil.

STUDIES IN THE DISEASES OF THE REPRODUCTIVE ORGANS OF CATTLE

Technical Bulletin No. 54

BY E. T. HALLMAN

PART I

A Preliminary Report on the Pathology of Pyometra in Cattle

INTRODUCTION

The cases reported here were from two herds in which abortion disease has caused more or less losses for the last six or eight years. Those who have had much experience in the handling of herds affected with abortion disease appreciate the frequency with which pyometra occurs as a sequel of abortion infection and the difficulties encountered in its treatment. Little, if any, work has been done in this country on the pathology of this condition in cattle and appreciating the importance of a knowledge of the pathology of any affection as a guide in outlining a rational treatment the writer deemed it advisable to devote some time to its study. The data presented here are not as extensive as the writer would like but it is not easy to secure satisfactory cases for pathological study and it is believed that this preliminary report is of sufficient importance to present for consideration.

Case No. 27

History and Clinical Examination: Guernsey cow five years old, calved March 9th, 1919 and retained the afterbirth. This was removed by an attending veterinarian but was followed by considerable discharge for a few days. Cow was bred on March 25, March 30th, April 30th, May 10th, and May 19th, 1919. She was in heat again on May 29th and June 20th but was not bred. A thick, yellowish vaginal discharge was observed when in heat on June 20th. On June 22, 1919 a clinical examination demonstrated the presence of about six ounces of a yellow muco-purulent exudate in the vagina, the external os uteri relaxed, cervical mucosa moderately congested, the uterus slightly enlarged and wall flaccid. There were two cysts each about ten mm. in size in the right ovary. The cysts were then ruptured, and the uterus irrigated with warm sodium bicarbonate solution followed by the injection of one dram iodoform, two drams bismuth subnitrate and two ounces of mineral oil into the uterus. June 29th there is a small quantity of a yellow muco-purulent exudate in vagina and the cervix is slightly congested. There is a tumor-like swelling about five centimeters in diameter dorsal to the cervix, and which contains a fluctuating fluid. The uterus is only moderately enlarged. The uterus was again treated as noted above. On July 5th there is some muco-purulent discharge in vagina. The peri-cervical abcess capsule is more dense and contents less fluctuating than one week ago. Two ounces of iodoform-bismuth-oil preparation were injected into uterus. This treatment was continued at weekly intervals for the next three or four weeks with but little improvement. During the first week of August this cow had a fracture of the pelvis and no further treatment was given. She was slaughtered on September 14, 1919.

Macroscopic Examination: Dorsal and to the right of the bifurcation of the uterus there is a sharply circumscribed encapsulated abscess about seven centimeters in diameter, containing a thick creamy granular pus. This abscess communicates with the posterior end of the right horn by a small canal directed backward. There is a small quantity of mucus in external os containing but a few flakes of pus. The mucosa of the cervix is a fairly uniform light drab color. There is some hypertrophy of the second transverse fold of the cervix. The left horn is somewhat larger than the right and contains about four fluid ounces of a sero-purulent exudate. The gland mucosa of the uterine body and left horn is mottled and varies in color from that of a yellowish gray to a reddish brown. There are distributed over the mucosa some twelve to fifteen small cyst-like structures projecting slightly above the surface and varying from one to three millimeters in diameter. These appear to contain a clear fluid. In addition to these there are a larger number of small circumscribed areas varying in size from one to two millimeters in diameter, the center of which appears as a dark gray spot varying from one half to one mm. in diameter, surrounded by a small peripheral zone apparently containing a clear fluid. The cotyledons vary in size from three by eight mm. to six by ten mm.; they are of a lighter color than that of the gland mucosa. The cotyledons bear some resemblance to pig's liver, the lobules of which are extremely fatty. These light yellow lobule-like areas vary in size from that of a pin point to one mm. in diameter. The mucosa of the right horn is of a more uniform yellowish gray color than that of the left horn. The cotyledons are a lighter color and are about one half the size of those of the left horn. The right ovary is six centimeters in diameter and has three well marked cysts fifteen to eighteen mm. in diameter. A non-motile gram negative gas producing rod of the colon group was isolated from the uterine exudate.

Histological Examination: The mucosa of the uterine body and left horn is three to four mm. thick and is covered with epithelium averaging about sixteen microns high. Most of the epithelial cells show very poorly stained or unstained nuclei. There is a marked leucocytic infiltration and proliferation of fibroblasts throughout the stroma but the resulting density is greater toward the mucous surface than toward the muscularis. The glandular changes are not marked although a few leucocytes are seen in some of the gland tubules. There are many oval shaped cysts in the mucosa varying in size from four-tenths by eight-tenths mm. to two by four mm. These cysts are lined with columnar epithelium averaging about twelve microns high and the connective tissue just without has been modified to produce a definite cyst wall. Some of the cotyledons are covered with a stratified squamous epithelium consisting of five or six layers, the outer layer or two of which appears to be cornified. The stroma of the cotyledon is more densely infiltrated with leucocytes and endothelial cells than is the stroma of the gland mucosa. The mottled appearance of the cotyledons described in gross is apparently due to the marked leucocytic and endothelial cell infiltration of the stroma. That is, normally, the minute blood vessels of the cotyledon are arranged in several groups containing three or four vessels in some groups to as many as twenty or even more in others. In places these groups of vessels are within a small fraction of a mm. of the surface. In this case the sub-epithelial tissue is densely packed with leucocytes and endothelial cells, the zone being shallow or deep depending upon the proximity of a group of blood vessels to the surface.

The mucosa of the right horn averages about four mm. in thickness and is covered by a simple epithelium more uniformly stained than is that of the left horn. There is a leucocytic infiltration of the stroma but less marked than in the left horn. There is also a diffuse fibrosis, more marked toward the surface.

Case No. 28

History and Clinical Examination: Case 28, aborted a six months old fetus November 1, 1919 and, on account of not being a very valuable animal and the desire of the owner to get her out of the herd, was killed on November 11, 1919.

Macroscopic Examination: The right (post pregnant) uterine horn is about three times the size of the left horn, the latter about twice the size and length of a normal non-pregnant horn. The right ovary contains a grayish yellow corpus luteum five mm. in diameter. The left ovary contains a bright yellow corpus luteum five mm. in diameter in the center of which is a small hemorrhagic area. The left ovary also contains a cyst-like structure twelve mm. in diameter and three or four smaller ones. The external os is open and the cervical mucosa is only slightly injected with a few scattered petechiae. The uterine cavity contains about two hundred and fifty cc. of a purulent exudate, distributed throughout the body and both horns. The gland mucosa is only moderately congested and there are present numerous small grayish white slightly raised circular areas varying in size from one half to one mm. in diameter in the center of which is a slight depression. These are apparently the swollen ducts of the uterine glands. The intervening gland mucosa consists of narrow interlacing areas of a more pinkish color. The cotyledons vary in size from twelve to thirty mm. in their longest diameter. They are of a yellowish gray but not uniform color. There are scattered quite thickly over the entire surface of the cotyledon small grayish yellow irregularly shaped areas. Some of these are circular and about the size of a pin point, others are elongated and average about one mm. in diameter. These are probably the swollen orifices of the crypts.

A cultural examination was not made of the exudate in this case but examination of stained smears demonstrated the presence of a streptococcus and a short small rod resembling the abortion bacillus.

Histological Examination: The epithelium of the cervix shows some, but not marked, mucoid changes. In places numerous leucocytes are seen passing through the epithelium. There is not a diffuse leucocytic infiltration of the sub-epithelial tissue but there are numerous foci of densely infiltrated areas. Here lymphocytes predominate but numerous plasma cells are seen. A few more deeply seat-foci of leucocytes are seen in the mucosa. Some hyaline degeneration of the muscularis is seen.

The gland mucosa of the body and right horn averages three to four mm. in thickness. The epithelium is denuded in most places but where present it varies from eight to twenty-four microns in height. In a few places it is observed that the epithelium is necrotic. In others there is evidence of regeneration of the epithelium. There are a few local areas of a superficial necrosis of the stroma in the denuded areas, the necrosis extending to a depth of fifty to sixty microns. There is a marked leucocytic infiltration of the superficial portion of the stroma. Here lymphocytes predominate although numerous fibroblasts and plasma cells are seen. The glandular lesions are not marked though in many of the gland tubules detached eipthelial cells and leucocytes are seen and in places the peri-glandular tissue is more cellular than in others.

There is a superficial diffuse necrosis of the cotyledons averaging about one-half mm. in depth. The crypts are poorly defined. What remains of them appear as irregular areas more or less filled with detached epithelial cells, placental cells and leucocytes. Occasionally there appear in the crypts what may be taken as the remains of a chorionic tuft. The crypts extend to a depth of two to two and one-half mm.

The mucosa of the left horn only differs from that of the right in that there is apparently more normal epithelium. In places, however, the same superficial necrosis and leucocytic infiltration is observed.

Case No. 29

History and Clinical Examination: Guernsey cow about eight years old. Her previous breeding record is unknown. She calved at full time March 28, 1920 and retained the afterbirth. Two days later the attending veterinarian attempted to remove it but could remove only a part of it. The uterus was irrigated with physiological sodium chloride solution and then one dram of iodoform, two drams of bismuth subnitrate suspended in two ounces of mineral oil was injected into the uterus. Two days later more of the afterbirth was taken away and the same treatment given as noted above. On April fifth it is recorded that the pulse and respiration are increased, there is a loss of appetite, diarrhea, and the animal is in a very weak condition. More of the afterbirth is removed and the same treatment given as noted above. Stimulative treatment is begun on this date. On April sixth there is a purulent discharge in vagina but the uterus is apparently free of afterbirth. There is no improvement in the general condition of the animal. The daily vaginal (antiseptic douch) and stimulative treatment is continued with no improvement in the general condition. On April thirteenth symptoms of pneumonia appear. Animal continues to grow worse and is killed on April nineteenth on account of a moribund condition due to a bilateral lobar pneumonia.

Macroscopic Examination: There is a small quantity of muco-purulent exudate in the anterior part of vagina and cervical canal. The cervical canal is nine cm. in length. The mucosa is of a fairly uniform yellowish gray color except at the crest of the folds where it is slightly injected. The left lateral portion of the first transverse fold of cervical mucosa is slightly hypertrophied and slightly injected. The uterine body is five cm. in length and the mucosa is covered with a thin layer of a thick adhesive purulent exudate. On scraping this away the mucosa is seen to be of a mottled steel gray color with a few bluish black areas that appear to be old hemorrhages. The left horn is about twice the size of the normal horn of a non-pregnant cow that has had one or more calves. The wall varies in thickness from six mm. at the posterior end to three mm. at the middle and anterior end. The mucosa of the posterior end is of a dirty yellow uniform color except near the base of the cotyledons; here the mucosa has a pinkish tinge. The appearance of the mucosa changes toward the middle of the horn, particularly near the base of the cotyledons, where there is a thin, but not uniform adhesive purulent exudate adherent to the cotyledons and parts of the gland mucosa. The gland mucosa is of a peculiar appearance. This can be illustrated best by comparing it with the cut surface of pigs liver where the intra-lobular tissue is considerably swollen, of a light gray color and stands above the interlobular tissue. That part which corresponds to the interlobular tissue is of a darker color and near the cotyledons shows what appears to be numerous petechiae. In the anterior end of the horn there is a greater amount of thick purulent exudate found than in the middle portion but here there is not more than one or two tablespoonfuls. The appearance of the mucosa differs from that of the middle portion in that the part which was compared with the swollen intra-lobular tissue of pigs liver appears to have contracted some and is of a steel gray color, and the inter-lobular like portions are lighter and free from petechiae.

The cotyledons of the left horn are of a darker color than that of the gland mucosa and vary in size from three mm. to six mm. in diameter and project above the surface from five to eight mm. A thin layer of an adhesive purulent exudate is adherent to most of the cotyledons in the middle and anterior portion of the horn. Upon scraping this away a few small yellowish gray spots are seen on the surface which suggest necrotic foci.

The right horn is not enlarged. The mucosa is of a light drab uniform color except near the base of a few cotyledons in the middle portion where it is apparently more vascular. The cotyledons are a lighter color than the gland mucosa and apparently normal. There is no abnormal exudate in the right horn.

In the left ovarian ligament there is a cyst about ten mm. in diameter and containing a sero-purulent exudate. The left ovary is twelve by twenty-five mm. in size and contains a corpus luteum about six mm. in diameter. The right ovary is ten by twenty mm. in size.

Streptococcus viridans and **Bacillus coli communis** were isolated from the uterus.

Histological Examination: The epithelium of the cervical mucosa shows rather marked mucoid changes. The mucosa of the uterine body varies from one to five mm. in thickness. There is a superficial necrosis of the mucosa varying in thickness from forty to three hundred and twenty microns. This necrotic zone which is quite general appears as a pinkish granular mass in which numerous leucocytes are seen. Only a few living superficial epithelial cells are seen; in most places the epithelium is not recognizable. Below the necrotic zone there is a distinct diffuse leucocytic infiltration of the mucosa to a depth of about one half mm. In addition to this, there is a marked increase in the number of leucocytes throughout the stroma. Numerous budding capillaries are seen in the stroma underlying the necrotic zone, beautifully illustrating the defensive and reparative activity of the stroma. The glandular changes are not marked although a few leucocytes and granular detritis are seen in some of the gland tubules and in places the glandular epithelium has retracted from the basement membrane leaving a clear zone around the epithelial lining. The mucosa of the posterior end of the left horn shows a superficial necrosis only in relatively small areas and where seen the necrotic zone does not extend to as great a depth as in the uterine body. Over larger areas of the surface the necrosed parts have apparently sloughed. Those portions of the mucosa not showing necrosis are in places covered by epithelium, in others they are bare. In places the epithelium is low cuboidal or squamous and does not completely cover the surface. At other places the height of the epithelium is normal but is not continuous, there being spaces between many of the cells. At still other places the epithelium is apparently normal. In that portion of the mucosa showing regeneration of the epithelium the sub-epithelial zone does not show a marked leucocytic infiltration. The stroma is more dense than the normal uterine stroma; this is more apparent toward the epithelium than toward the muscularis; numerous endothelial cells and fibroblasts are seen.

The mucosa of the middle portion of the left horn averages about two and one-half mm. in thickness. In places there is a superficial necrosis averaging sixty-five microns in depth. In other places no necrosis is observed but the mucosa is bare of epithelium and still in others the mucosa is covered by regenerated epithelium. The peculiar appearance of the mucosa described in gross is due to the swollen condition of the mucosa between the gland ducts. This swelling is the result of a leucocytic infiltration of the stroma, proliferation of the endothelial cells and fibroblasts and the new formation of capillaries. These changes are more marked in the outer portion of the stroma and diminish rapidly toward the deeper portions. The orifices of the gland ducts are filled with a pinkish granular detritis in which numerous leucocytes, erythrocytes and a few epithelial cells are seen. In the region of the cotyledons the necrosis is more uniform and there are numerous petechial hemorrhages in the superficial portions. In the anterior end of the left horn, the necrotic zone, where it has not sloughed off averages about one hundred and fifty microns deep. At places however, it dips down into the stroma to a depth of one-half to seven-tenths of a mm. giving rise to minute ulcers. There is apparently a greater proportion of fibroblasts in the sub-necrotic stroma than in the middle portion of the horn.

Case No. 30

History and Clinical Examination: Cow about nine years old, aborted a seven months old fetus September 27th, 1920. The afterbirth was retained and removed by attending veterinarian. On September 29th there were symptoms of pneumonia and a putrid discharge from uterus. She was placed on stimulative treatment and one ounce of boric acid was introduced into uterus. Uterus was irrigated on the 30th and a boric acid capsule introduced into uterus on October 4th. After this only vaginal treatment was given locally and the stimulative treatment continued. The animal progressively got weaker and died on the night of October 24th, 1920. Autopsy demonstrated a septic embolic pneumonia, suppurative mammitis and purulent endometritis.

Macroscopic Examination: The external cervix is covered with a thick gray purulent exudate. The first fold of the cervical mucosa is highly congested and hypertrophied. Cervical canal is seven cm. in length. The mucosa is of a steel gray color. Body of uterus is three cm. in length and the mucosa is covered with a thick gray pus. On scraping this away the mucosa is seen to be of a steel gray color. The right horn is about twice the size of a non-pregnant normal horn; the mucosa is covered with a thick gray pus in which is seen numerous small brownish black granules about the size of a mustard seed, probably precipitated constituents of blood. The appearance of the gland mucosa is similar to that of the uterine body. The cotyledons average about eight by twelve mm. and project above the surface six to eight mm. They are of a steel gray but lighter color than that of the gland mucosa. There is a thick gray purulent exudate adherent to the surface.

The left horn is but slightly enlarged. The mucosa is similar to that of the right horn and is covered by a similar exudate. There is no enlargement of either oviduct and no apparent alteration of either ovary.

Unfortunately, cultural examination was not made of the uterine exudate in this case. Microscopic examination of smears from the uterus demonstrated a streptococcus and a small short rod. The former apparently predominating.

Histological Examination: In places the epithelium of the cervical mucosa show but slight changes. In others there is marked disintegration of the epithelium, with necrosis, where there is a granular exudate adherent in places to the surface and a leucocytic infiltration of the sub-epithelial tissue, lymphocytes apparently predominating. In some of the capillaries and other small vessels is seen varying amounts of fibrin. In some of the vessels the amount of fibrin is small, in others their contents have somewhat the appearance of a thrombus.

The mucosa of the uterine body and right horn varies from two to three mm. in depth except in places where the superficial necrotic process has extended to a depth of six-tenths to one mm. from the muscularis producing ulcer like areas. There is a general superficial necrosis of the mucosa averaging about eight-tenths mm. in depth. There are but few leucocytes in the necrotic zone. There is a distinct but not marked leucocytic infiltration of the stroma below the necrotic zone, lymphocytes predominating. In many of the small vessels of the mucosa masses of fibrin containing varying quantities of red blood cells, and leucocytes are seen, which in places almost completely fill the lumen. The condition of the uterine glands varies. In places they are apparently normal, in others there is disintegration of the epithelium with leucocytic infiltration of the gland lumen. The alterations of the mucosa of the left horn are similar to those of the right.

There is not as marked a leucocytic infiltration of the mucosa in this case as is seen in the others of this series. Whether this indicates a lack of resistance or.is due to the drain on the hemopoietic organs by the respiratory system and udder is an interesting speculation.

SUMMARY

In three cases out of the four studied a superficial more or less general necrosis of the mucosa with leucocytic infiltration and fibrosis of the superficial portions of the stroma were.observed. The necrotic zone varied in depth from fifty microns to eight-tenths of a mm. and in places producing many minute ulcers extending more deeply into the uterine mucosa. Both the gland mucosa and the region of the cotyledons were involved in the necrotic process. The glandular changes as a whole were not marked although in places there was degenerative and disintegrative changes in the glandular epithelium with leucocytic infiltration of the gland luminae. In one of these cases, numerous thrombi were seen in the small blood vessels of the mucosa more or less completely plugging them. The lesions observed in these cases bear considerable resemblance to those caused by the injection of concentrated preparations of iodine into the uterine cavity. There is this important difference, however, in the latter case. Here the principal irritant is quick in its action and is active for only a short period of time. In pyometra the irritation is continuous over a longer period of time. This condition obviously produces more fibrosis.

In one of the cases studied the most conspicuous alteration was the presence of numerous small cysts in the uterine mucosa. This condition, may explain failure to breed and nymphomonia in those cases in which clinical examination fails to reveal cystic ovaries. Obviously these small cysts in the uterine mucosa could not be detected clinically. It is possible that many of them might be crushed by massage. In this case there was some necrosis of the epithelium with leucocytic infiltration and some fibrosis of the stroma. Over some of the cotyledons the epithelium was stratified, the outer layers of which were apparently undergoing cornification. Sven Wall of Sweden has reported this condition not only of the cotyledon but also of the gland mucosa, and believes that it results from a growing in of the ectodermic epithelium from the vagina. Since this condition was not observed in the gland mucosa of the case studies by the author, he is inclined to look upon it as not the result of a growing in of the epithelium from the vagina but more likely the result of constant irritation of a relatively low degree of the epithelium of the cotyledon.

The alterations observed in these cases suggest the thought that the most helpful treatment is that which would provide constant drainage and prevent putrefaction of the necrotic tissue.

PART II

Some Observations on the Anatomical Effects of Medicinal Agents on the Uterine Mucosa of the Cow

INTRODUCTION

The data presented here were collected in an effort to throw some light on the gross and microscopic changes produced in the uterine mucosa by the application of the treatment usually employed by gynecologists for the chronic catarrhal conditions of the uterus. The application of irritants in concentrated form for the chronic inflammations of mucous membranes is a long established practice. The human gynecologist frequently combines curettage with this treatment for chronic endometritis. The assumption is that the reaction produced by such treatment will destroy the deep seated infection causing the chronic condition. Gynecologists have warned against the use of such heroic treatment for the uterine affections, pointing out that the uterine mucosa is a delicate structure and that the damages wrought by such treatment may be greater than the primary affection. The writer knows of no data, other than clinical, that either proves or disproves this assumption. In the work recorded here no effort was made to determine the effects of such treatment on the bacterial flora of the uterine mucosa. In fact no effort was made to select cases suffering with the chronic affections.of the uterus. The primary object of the work was to make some observations on the damages wrought by such treatment and the extent of repair of the uterine mucosa. The method followed in this work was to select non-pregnant cows that had had one or more calves and were to be slaughtered for beef, note the clinical condition of the reproductive organs, apply the medicinal agent and then slaughter the animal and record the gross and histological changes of the mucosae. Each cow reported here was from a dairy herd representative.of the common dairy breeds. Only two preparations have been used in this preliminary work, viz. (1) Lugol's solution of iodine, and (2)the following preparation: menthol crystals, two drams; tincture of iodine, two ounces;

and glycerine, two ounces. Lugol's solution of iodine has been quite generally used for a number of years in the treatment of affections of the uterus and the menthol-iodine-glycerine preparation has been used quite extensively in the last two or three years. This work is by no means complete but the results have proved to be of such interest to the writer that it is deemed advisable to publish them for the consideration of those interested in this problem.

Case No. 1

Clinical Condition and Treatment: The vagina contained a considerable quantity of thin clear mucus as in heat. The cervix was slightly enlarged with some hypertrophy of the second transverse fold. The mucosa was only slightly congested and excessively moist. The uterus and ovaries were apparently normal. One ounce of undiluted Lugol's solution of iodine was injected into the uterus and the uterus gently massaged to force the solution into all parts of the cavity. The cervix was then swabbed with the same preparation. (This technique was followed in each case reported here). The animal was slaughtered seven and one quarter hours after the treatment.

Macroscopic Examination: There is considerable stringy fibrinous exudate adherent to the external cervix. The cervical mucosa is considerably congested except in the deeper portions of the commissures and where the mucosa was protected by the overlying transverse folds. There are one or two ounces of a straw colored serous exudate in the uterine cavity in which is seen two or three teaspoonfuls of a coagulated fibrinous material. The mucosa of the uterine body shows marked congestion but not as marked as that of the cervix. The congestion diminishes toward the anterior end of the horns where it is hardly noticeable.

Histological Examination: It was not possible to obtain entirely satisfactory sections of this case especially from the cervix due to an error in technique. The epithelium of the mucosa of the horns is denuded in most places (apparently mechanical), where present it varies from eight to sixteen microns in height; the cells are cloudy and the nuclei poorly stained. In places there is some coagulum consisting of red blood cells and a granular material adherent to the surface. At a few places the epithelium is separated from the sub-epithelial stroma by a thin layer of what appears to be disintegrated red blood cells. The blood vessels of the stroma are more or less engorged and there is some edema of the stroma. In places quite a considerable number of leucocytes are seen in the edematous areas. A few sub-epithelial hemorrhages are observed.

Case No. 2

Clinical Condition and Treatment: Cervical secretions and mucosa apparently normal, uterus and ovaries apparently normal. One ounce of menthol-iodine-glycerine preparation was injected into uterine cavity and an effort was made to swab the cervix but on account of the smallness of the canal it was not effectively done. The cow was killed six hours after treatment.

Macroscopic Examination: External os contains a muco-fibrinous plug. Cervical mucosa is considerably congested. There are about two ounces of straw colored serous exudate containing a few flakes of fibrin, in uterine cavity. The mucosa is only slightly congested.

Histological Examination: The cervical mucosa shows numerous sub-epithelial hemorrhages at the crest of the folds. Here the epithelium in places is denuded, at others it is well stained even in places where there are numerous sub-epithelial hemorrhages. In the pits between the folds, the mucosa shows no effects of treatment. The uterine mucosa to a depth of about two-tenths mm. shows a distinct zone in which the capillaries are engorged and there is marked edema. The superficial epithelium is cloudy and more granular than normal but the nuclei are well stained.

Case No. 3

Clinical Condition and Treatment: Cervical secretions abundant as in heat. Cervical mucosa slightly congested and canal open. No abnormality of uterus or ovaries could be detected, clinically. One ounce of Lugol's solution of iodine diluted with one ounce of water was injected into uterus and the cervix was swabbed with undiluted Lugol's solution. The cow was slaughtered twenty-nine hours after treatment.

Macroscopic Examination: On the dorsal surface of the posterior end of the right horn is a circumscribed slightly raised yellowish gray area surrounded by a hemorrhagic zone. This lesion is two and one-half by five cm. in size. There is about one teaspoonful of a muco-fibrinous exudate.in external os. The cervical mucosa is highly congested and shows numerous petechial hemorrhages, especially along the dorsal surface. There are about three ounces of a straw colored serous exudate in uterine cavity. In addition to this there are two muco-fibrinous clots, the larger of which begins in the right horn and extends around into the left horn. It is about twenty cm. in length, irregularly cylindrical and a little larger than a lead pencil.

Near the middle of the left horn there is a small amount of coagulated blood. The uterine mucosa is congested, more marked in the right than the left horn. The mucosa over the circumscribed lesion described above is roughened and of a greenish tinge. On section of this lesion a sero-sanguineous clot twelve mm. in diameter is seen in the deeper layers of the uterine wall (hematoma).

Histological Examination: The alterations in the cervical mucosa are not general but are confined to the crest of the folds. Here there is a more.or less diffuse hemorrhagic zone the average depth of which is about one hundred and fifty microns. The epithelial changes over these areas, while marked are not extensive. At places they are shrunken to one-half their normal height and many of them show no nuclei, at other places where there are extensive sub-epithelial hemorrhages the epithelium shows no changes. In a few scattered areas the epithelium is denuded. The sub-epithelial capillaries are engorged and there are many diffuse sub-epithelial hemorrhages. There is no well marked leucocytic infiltration of the hemorrhagic areas although in a few small areas there appears to be a slight increase in the number of leucocytes. There is but little evidence of reaction on the part of the fixed connective tissue cells in the hemorrhagic areas. In the pits formed by the folds and in the tubular depressions the mucosa shows no changes.

There is a superficial necrosis of the uterine mucosa, involving in most places only the superficial epithelium. In a few places however, the necrotic process dips down into the stroma. The epithelium is denuded in places, where present it varies from six to twenty microns in height and the nuclei are unstained. In places there is a sub-epithelial zone varying in depth from eighty to five hundred microns, in which the nuclei of the cells are more faintly stained and edema more marked than in the deeper portions. The blood vessels of the stroma are engorged and there is marked edema, and in places numerous leucocytes are seen in the edematous areas.

The glandular changes are not marked. Only in a few areas is there any evidence of slight necrosis of the superficial glands.

Case No. 4

Clinical Condition and Treatment: Other than the vaginal and cervical secretions being rather abundant no alterations of the reproductive organs could be detected clinically. Two ounces of menthol-iodine-glycerine preparation were injected into the uterine cavity and the cervix swabbed with same. The animal was killed forty-eight hours after treatment.

Macroscopic Examination: The cervical mucosa is considerably reddened and shows numerous hemorrhages, especially near the borders of the transverse folds, except that portion of the mucosa protected by the overlying folds which is but slightly congested. There is a small amount of fibrinous exudate in cervical canal. The uterine mucosa is congested and shows numerous small hemorrhages and the surface is covered with a rather abundant coagulated fibrinous exudate. This exudate extends into the anterior ends of the horns but is less abundant there than toward the posterior end. The deeper portion of the uterine wall is edematous.

Histological Examination: There is but little evidence of necrosis of the cervical epithelium. The sub-epithelial capillaries are engorged and there are numerous more or less diffuse hemorrhages along the crest of the folds. Only in places are hemorrhages seen in the region of the pits. Considerable edema is seen in places in the stroma. In the uterine mucosa there is a diffuse superficial necrotic and hemorrhagic zone to an average depth of five-tenths millimeter. Just below this there is a distinct zone of leucocytes, principally polymorphonuclears and lymphocytes. At places the necrotic zone is separated from the underlying stroma by a longitudinal fissure as if being detached. There is engorgement of the capillaries and edema throughout the stroma.

Case No. 5

Clinical Condition and Treatment: The vaginal secretions were excessive, slightly more tenacious than the secretions of estrum, and contained a few flakes of pus. The cervical mucosa normal in color but excessively moist. Right horn of uterus slightly larger than the left, otherwise no alterations could be detected clinically. One ounce of Lugol's solution diluted with one ounce of water was injected into uterine cavity and cervix swabbed with undiluted Lugol's solution. The animal was killed seventy-nine hours after treatment.

Macroscopic Examination: There is about one ounce of a sero-mucus exudate in the vagina. There are a few small hemorrhages in the ventral vaginal mucosa posterior to the external os. The cervical mucosa is moist but slightly congested and shows a number of petechial hemorrhages. The right uterine horn is slightly enlarged. There is a coagulated fibrinous exudate in the cavity of the right horn extending well toward the anterior end. The mucosa is not uniformly congested but the congestion is more intense in the anterior two-thirds and along the crest of the folds. Between the folds, the mucosa is but slighlty congested. The uterine wall is edematous. There is a smaller quantity of a sero-fibrinous exudate in left horn than in right, the mucosa is not congested and is moist.

Histological Examination: The epithelium of the posterior cervix is squamous except in the tubular depressions and shows considerable mucoid changes. At some points the superficial cells have elongated and shrunken nuclei and the cytoplasm is more densely stained than is seen in the normal condition. This somewhat resembles the superficial layers.of the cutaneous epithelium and possibly.illustrates the process of exfoliation of the cells injured by the treatment. In the deeper layers of the epithelium the nuclei are larger and vesicular and numerous mitotic figures are seen. The epithelium of the middle cervix is simple columnar and shows the same condition seen in the post cervix except in a few places it appears as a necrotic membrane. At places there is marked eosinophilic infiltration of the sub-epithelial stroma.

In the posterior end of the right horn the epithelium varies from four to twenty-four microns in height. The cells are deeply stained and numerous mitotic figures are seen. At places there are epithelial buds projecting above the surface to a height of forty microns at some points. This is interpreted as excessive regeneration. The tips of these buds have a greenish tinge which is probably a necrobiotic condition. At places along the surface the epithelium is denuded and the process of the adjacent cells flattening and extending out over the denuded area, and the intermediate stages of regeneration can be distinctly seen. In the middle portion of the right horn the epithelium is denuded although in places the necrotic epithelial membrane is present but is separated from the stroma by exudate consisting of coagulated fibrin and numerous polymorphonuclears. Here the mucosa varies from two to six mm. in thickness and there is a distinct superficial zone averaging about eight-tenths mm. in thickness in which the capillaries are engorged and the tissue more or less necrotic. Numerous leucocytes are seen in this zone. There is some evidence of proliferation of the fixed connective tissue cells at the border line of this zone and the more deeply seated stroma. In the anterior end of the right horn the necrotic epithelium remains throughout most of the sections studied. The same hemorrhagic and necrotic zone is seen as described.in middle portion. The necrotic tissue is densely infiltrated in places with leucocytes. At places the superficial part of this zone including the epithelium and part of the stroma is beginning to slough by a process of liquefaction necrosis. At other places a layer of simple squamous epithelium is seen covering the eroded areas where the necrotic zone is still present but being separated by liquefaction necrosis. In places this may be seen at a depth of one mm. from the surface and is seen to result from a proliferation of the epithelium of the gland ducts. This observation illustrates that regeneration of the epithelium may be initiated even before the superficial necrotic tissue is sloughed and testifies to the logic of the adage "There is in the tissues an almost insuperable tendency to heal." This capacity of the epithelium to initiate regeneration at an early time after irritation with destruction is of importance in preventing the growing together of surfaces of mucous membranes that are in contact where the epithelium and superficial parts of the stroma have been destroyed by irritation, a condition which does occur at times, as is sometimes seen after swabbing the cervix with irritants. This property of epithelium also explains the difficulty of surgically eliminating fistulous tracts that have become lined with epithelium.

In the left horn the process of repair of the mucosa is more advanced. The necrotic zone has largely sloughed and the surface is more generally covered with epithelium. At places the epithelium is only six to eight microns in height, at other places it shows extensive budding and is in excess of the normal height. There is no apparent leucocytic infiltration of the stroma, no marked fibrosis and the sub-epithelial zone is assuming a more normal condition.

Case No. 6

Clinical Condition and Treatment: The record of the clinical examination of this case before treatment was lost. Two ounces of menthol-iodine-glycerine preparation was injected into the uterus and the cervix swabbed with the same preparation. The cow was slaughtered seventy-eight hours after treatment.

Macroscopic Examination: There is about one ounce of mucus exudate streaked with pus, in the vagina. The vaginal mucosa shows a few small hemorrhages. The dorsal portion of the cervical mucosa is considerably congested. There are a few hemorrhages on the crests of the transverse folds, particularly in the posterior half of the cervix. Aside from the dorsal portion, the mucosa of the anterior half is more nearly normal. There is no coagulum in the uterine cavity. The color of the mucosa is a fairly uniform slightly grayer than the normal mucosa. There is present a small quantity of mucus and the mucosa is moist and glistening.

Histological Examination: Except for some mucoid degeneration of the epithelium and a few sub-epithelial hemorrhages, the cervical mucosa is normal. The uterine mucosa is covered with epithelium, although in places it is only four to eight microns in height. There is a more or less distinct sub-epithelial zone in which there is some leucocytic infiltration. There are no alterations in the deeper portions of the stroma. Here and there, near the surface a gland is seen in which there is an epithelial cast. In these cases the glandular epithelium has been regenerated. Occasionally a distinct localized small round cell infiltration of the sub-epithelial zone is seen. (It is surprising that so few alterations are seen in this case.)

Case No. 7

Clinical Condition and Treatment: The vaginal and cervical secretions were slightly more abundant than is seen normally. The ventral portion of the second transverse cervical fold was hypertrophied and congested. No alterations of the uterus could be detected. One ounce of undiluted Lugol's solution was injected into uterus and the cervix swabbed with the same preparation. The animal was slaughtered eleven days and five hours after treatment.

Macroscopic Examination: The ventral portion of the second transverse fold of cervical mucosa is hypertrophied but the color is normal. There is a small quantity of slightly adhesive clear exudate in cervical canal. The uterine mucosa is a uniform, yellowish gray color. There is no abnormal exudate.

Histological Examination: There are no alterations of the cervical mucosa. The mucosa of the right horn is covered by a continuous layer of epithelium. The sub-epithelial zone of the stroma does not appear to be as cellular as is seen in the normal uterus. There are no other alterations of the right horn. The mucosa of the left horn is also covered by a continuous layer of epithelium. There is no distinct sub-epithelial cellular zone but this layer is more fibrous than in the normal uterine mucosa. The mucosa varies from six to eight mm. in thickness. It is not conceivable that this thickening is the result of the treatment administered eleven days ago. If such were the case there would now be evidence of an active fibrosis. It is more probable that it is due to a previous inflammation.

Case No. 8

Clinical Condition and Treatment: The cervical secretions were fairly abundant and streaked with blood as in the beginning of menstruation. Cervical mucosa not congested. Uterus firm, tense as if in heat. One ounce of undiluted Lugol's solution of iodine was injected into uterus and the cervix was swabbed with the same preparation. The animal was slaughtered eleven days and six hours after treatment.

Macroscopic Examination: Cervical mucosa is apparently normal. Near the posterior end of the left horn there is an irregularly cylindrical fibrinous coagulum one cm. by four cm. The mucosa at this point is roughened. Externally over this lesion which appears to be traumatic is a slightly raised area showing a few fibrous tags. Just below the internal os there is a hematoma about two and one-half cm. in diameter, in the uterine wall. The uterine mucosa is apparently normal with the exception noted above and the presence of a few distinctly injected sub-epithelial blood vessels in the uterine body and posterior end of left horn.

Histological Examination: There are no alterations in the mucosa of the uterine body and left horn except in proximity to the lesion described in gross. Here there is a small amount of exudate adherent to the surface and in places the epithelium is denuded. At places the epithelium is only six to eight microns in height, possibly indicating that regeneration is not yet complete. In the right horn, there are areas where the epithelium is only six to eight microns in height. At places there is a distinct periglandular fibrosis in the stroma although the periglandular tissue partakes of the nature of adult connective tissue and therefore is not likely the result of the treatment administered eleven days ago.

Case No. 9

Clinical Condition and Treatment: The cervical secretions were moderate in amount, clear and adhesive as in pregnancy. No alterations of the uterus could be detected clinically. One ounce of undiluted Lugol's solution of iodine was injected into uterus and the cervix swabbed with the same preparation. The animal was slaughtered fourteen days and six hours after treatment.

Macroscopic Examination: Cervical secretions are clear, and fairly abundant. The cervical mucosa is normal in appearance. The uterine mucosa is of a fairly uniform grayish yellow color and is moist and glistening except for a small area about three cm. in diameter near the middle portion of the right horn. Here the mucosa appears to be sprinkled with a very small quantity of coagulated exudate giving it a ground glass like appearance.

Histological Examination: No alterations are observed except for a small area in the right horn described in gross. Here there is observed in places, epithelial buds projecting above the surface. These have been described in a previous case and are interpreted as preverted or excessive regeneration of the epithelium. It is quite possible that these buds disappear in time since a condition which is interpreted as necrobiosis has been observed in them.

Case No. 10

Clinical Condition and Treatment. The cervical secretions were scant, slightly cloudy and adhesive. The second transverse fold of mucous membrane was hypertrophied and protruding through the external os. No enlargement of the uterus could be detected clinically. One ounce of undiluted Lugol's solution was injected into the uterus and the cervix was swabbed with the same preparation. The animal was slaughtered fourteen days and six hours after treatment.

Macroscopic Examination: The second transverse fold of the cervical mucosa is hypertrophied but the color is normal. Cervical secretions are not abundant but adhesive. At the lower border of the third fold there is a friable adhesion between two of the elementary folds. There are two fetuses apparently four or five weeks old, normal in appearance, in the left horn. The color of the uterine mucosa is fairly uniform and normal in appearance. There is an adhesion between the right horn and the anterior border of the bladder. Also about four inches from the anterior end of the right horn there is another adhesion between the right horn and the adjacent structures. These adhesions are of recent origin as they are easily detached. To the right and below the posterior end of the right horn there is a cavity between the folds of the broad ligament two inches by three inches in diameter containing a straw colored fluid and a coagulated fibrino-sanguineous mass. This is evidently a hematoma in the process of absorption. This cavity extends up to within a few centimeters of the ventral floor of the right horn but there is no evidence of perforation of the mucosa.

It is remarkable that the twin fetuses had survived the treatment administered fourteen days previous. The only logical explanation apparent to the writer is that the embryos had not descended into the cavity of the horn at the time of treatment.

No histological examination was made of this case.

Case No. 11

This case differs from the above ten in that she was treated by the author for pyometra with what might be considered from a clinical standpoint fairly satisfactory results. Since she was not a particularly valuable cow and the author was anxious to make a histological examination of the reproductive organs to determine the effects of heroic treatment on the uterine mucosa the owner kindly consented to slaughter her for beef.

History: Animal calved, apparently normally, about the first of December 1918. On December 24, 1918 the author's attention was called to this case on account of a vaginal discharge. Examination demonstrated considerable pus in uterus, due to **Streptococcus pyogenes** infection.

The uterus was douched with warm physiological salt solution and then two ounces of 50 per cent Lugol's solution of iodine was introduced into the uterus. The author did not see the cow again until January 25th, 1919 at which time there was about one pint of thick creamy pus in the uterus. The uterus was douched with a weak solution of coal-tar product and then one ounce of a 50 per cent solution in olive oil of a proprietary preparation consisting essentially of oil of tar, oil of peppermint and other volatile oils was injected into the uterus.

January 27th, no improvement, same treatment given as on January 25th.

January 29th, no improvement, same treatment given as on January 27th.

January 31st no improvement, irrigated uterus with weak solution of coal tar product followed by an injection of three ounces of 5 per cent solution of formalin.

February 7th some improvement noted. There is some purulent exudate in the uterus but not so much as at last treatment. Irrigated uterus with warm physiological salt solution and injected three ounces of 5 per cent solution of formalin into the uterus. Animal manifested severe uterine pain immediately following this treatment.

February 14th still considerable pus in the uterus. Irrigated uterus with salt solution and injected two ounces of undiluted Lugol's solution of iodine into the uterus.

February 19th, considerable improvement noted, very little pus found in the uterus. Uterus irrigated with salt solution to which was added about 0.5 per cent of a coal tar product.

February 25th, marked improvement, no pus in the uterus but right horn slightly enlarged. Wall thickened but no fluctuation. Cervical secretions excessive, slightly adhesive but practically clear. The cow was given vaginal douche of 1 per cent sodium bicarbonate and three-fourths of 1 per cent sodium-chloride solution. No further treatment was given and the animal was slaughtered for beef May 12, 1919.

Macroscopic Examination: External os slightly dilated but folds not apparently hypertrophied. Cervical canal ten cm. long, contains considerable clear mucus as in heat. Body of uterus three cm. long. Mucosa of grayish drab color apparently uniform. There is what appears to be a radiating cicatrix about one cm. in length by six mm. wide just anterior to the internal os. The right horn is about one-half larger than left horn and appears edematous. On section mucosa is of a grayish drab color fairly uniform though apparently more vascular in the dorsal than in the ventral part. Mucosa is apparently thickened and edematous. There is present some clear mucus. The cotyledons are apparently normal in number, vary in size from three to six mm. in diameter and the center of the cotyledon is more vascular than the periphery, the latter having a grayish yellow appearance. On close examination the gland mucosa is not uniform but there are numerous intercrossing and irregular small grayish lines which may represent the interglandular tissue. The left horn is very slightly if any enlarged and on section the mucous membrane appears edematous though the thickening is not so great as it is in the right horn. It has the same general appearance. Left oviduct is normal, left ovary is oval, four and one-half cm. in its greatest diameter and contains a cyst-like structure about one cm. in diameter and numerous small immature folicles. There has apparently been some contraction of the ovarian ligament between the anterior end of the right horn and ovary. The ligament is thickened at this point and the right oviduct is not observable except on close examination. The oviduct does not appear enlarged. Right ovary is about four cm. in length and contains a corpus luteum about one cm. in diameter.

Histological Examination: The mucosa of the cervix is covered in its posterior part by a stratified epithelium fifty microns high. Anteriorly, the epithelium is simple and averages about sixteen microns in height. In places the mucoid changes are well marked, in others they are absent. The sub-epithelial zone is but slightly cellular. The mucosa of uterine body varies in thickness from one and one-half mm. (in scar like area) to three mm. and is covered by an epithelium twelve to fourteen microns in height. The epithelium over the scar like area shows marked mucoid changes. Here the stroma is very dense and contains no glands. In the other portions of the uterine mucosa the sub-epithelial cellular zone is not distinct but is distinctly more fibrous than normal. There is a conspicuous diminution in the number of glands. Areas of a square mm. or more are seen in which there are no glands. However, numerous glands are seen with apparently normal epithelium. At one point, between a vein and artery, is seen a focus of transitional fibroblasts four hundred eighty by eight hundred microns in size. The mucosa of the horns varies from three to seven mm. in thickness and is covered by an epithelium ten to sixteen microns in height. In the epithelium are seen a few oval shaped cyst-like structures averaging eight by sixteen microns in size and containing a yellowish granular substance. The sub-epithelial zone is denser and slightly more cellular than the deeper portion of the stroma but the differentiation is not so distinct as in the normal uterus. There is a diminution in the number of glands and many glands with atrophic epithelium are seen but there are also many apparently normal glands. The periglandular tissue in general is slightly more cellular than the interglandular tissue, giving rise to the appearance observed in gross.

It was surprising to the writer that more fibrosis of the uterine mucosa with atrophy of the epithelium had not resulted from the pyometra and drastic treatment that had been administered.

SUMMARY

The injection of one ounce of Lugol's solution of iodine either undiluted or diluted with an equal volume of water, into the uterine cavity of the cow produces an acute fibrinous endometritis with superficial necrosis of the mucosa varying in depth from twenty microns to one millimeter. Injection of one or two ounces of menthol-iodine-glycerine has the same effect. Marked superficial necrosis is apparent the day following injection and sloughing of the necrosed tissue by a process of liquefaction necrosis is observed in forty-eight hours after treatment. Regeneration of the epithelium may be observed as early as seventy-eight hours after treatment, resulting in the partial covering of the eroded surface before the necrotic zone is completely detatched. This covering of epithelium results from a proliferation of the epithelium lining the gland ducts in case the superficial epithelium has been completely destroyed. Other than marked edema and engorgement of the blood vessels there is but little evidence of the effects of such treatment upon the deeper portions of the uterine mucosa. Out of ten cases treated there were three in which the treatment apparently caused the rupture of a blood vessel resulting in a hematoma. In one of these the cow was in heat, in another there was evidence of menstruation and the third was pregnant. In view of the fact that in each of these conditions there is an engorgement of the blood vessels, the thought is suggested that such treatment about the time of estrum or menstruation may be a dangerous practice.

The effects of swabbing the cervical mucosa with concentrated preparations of iodine are limited almost entirely to the crest of the folds. Here there is more or less necrosis of the epithelium with necrosis and capillary hemorrhages in the sub-epithelial tissue. In the pits and in the tube-like depressions there is little or no effects of treatment. The results illustrate that it is impossible to disinfect, even the surface of the cervical mucosa by the application of such preparations. Where beneficial results follow such treatment it is more likely that the good results are due to the inflammatory reaction of the tissues rather than to the destruction of bacteria. The inflammatory reaction is the expression of the mechanism of defense and repair in which more blood, meaning more leucocytes, more bactericidal substances, and more nutrition, are brought to the part. This with the greater activity of the tissues to overcome the destruction wrought by the drug incidentally overcomes the infection.

The condition found in cases seven, eight and nine indicate that repair is more or less complete in about two weeks from treatment. There is but slight, if any, evidence that any appreciable fibrosis results from one treatment of this nature. The thought is suggested by these observations that less fibrosis is likely to result from such treatment than might result from milder irritation over a longer period of time.

Grateful acknowledgment is here given to Prof. R. H. Pettit and Miss Eugenia McDaniel of the Department of Entomology for making the photomicrographs illustrating this bulletin.

EXPLANATION OF PLATES

Plate I.

Fig. 1. Case No. 27. Cysts in the uterine mucosa; X 10.

Fig. 2. Case No. 27. Stratified and cornified epithelium over a cotyledon; X 200.

Plate II.

Fig. 3. Case No. 28. Superficial necrosis of cotyledon in pyometra ten days after aborting. The crypts are poorly defined; X 72.

Fig. 4. Case No. 29. Uterine mucosa. Superficial necrosis, a, and leucocytic infiltration, b, of gland mucosa. In the process of healing sloughing would take place at c; X 72.

Plate III.

Fig. 5. Case No. 30. Superficial necrosis and leucocytic infiltration of gland mucosa. At a, a thrombus is seen in a bloodvessel; X 72.

Fig. 6. Case No. 30. Superficial necrosis and leucocytic infiltration of both the region of the cotyledon and gland mucosa. At a, and b, thrombi are seen in vessels; X 72.

Plate IV.

Fig. 7. Case No. 3. Cervical mucosa twenty-nine hours after treatment with Lugol's solution of iodine diluted with an equal volume of water. At the crest of the folds, a, the epithelium is shrunken and poorly stained. There are numerous petechial hemorrhages in the subepithelial tissue, b. In the pits, c, no effect of the treatment is seen; X 72.

Fig. 8. Case No. 3. Uterine mucosa; the epithelium is intact but necrotic, a. Note the engorgement of the blood vessels, b; X 72.

Plate V.

Fig. 9. Case No. 3. Uterine mucosa; here the epithelium is denuded, a, and there is a distinct edematous and necrotic zone, b. Marked leucocytic infiltration is seen at c; d indicates the line at which sloughing would have taken place; X 72.

Fig. 10. Case No. 4. Superficial necrosis of a cotyledon forty-eight hours after treatment with menthol-iodine-glycerine solution; a indicates where sloughing would have taken place; X 72.

Plate VI.

Fig. 11. Case No. 5. Uterine mucosa seventy-nine hours after treatment with Lugol's solution of iodine diluted with an equal volume of water. Sloughing of the necrotic zone by liquefaction necrosis, a. At b, is seen what would have been the surface of the recovered mucosa; here, there is a layer of simple squamous epithelium which, normally, would have grown into simple columnar; at c, is seen a portion of the wall of a gland duct from which the epithelium is flatening and growing out to cover the eroded surface. Observe that the surface is being covered with regenerating epithelium before the necrotic zone is completely detached; X 72.

Fig. 12. Case No. 9. Uterine mucosa fourteen days and six hours after treatment with undiluted Lugol's solution of iodine. No fibrosis can be seen; X 72.

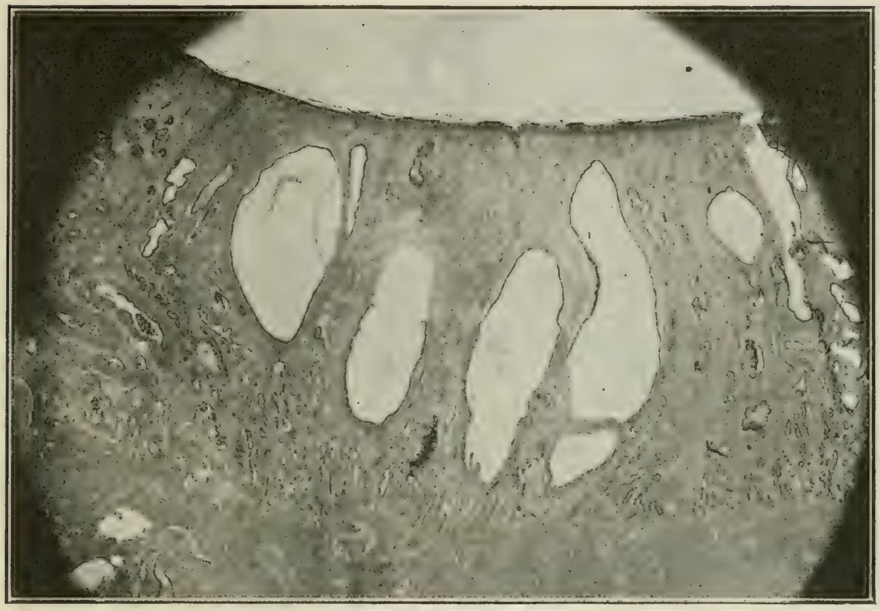


PLATE I.—FIGURE 1.

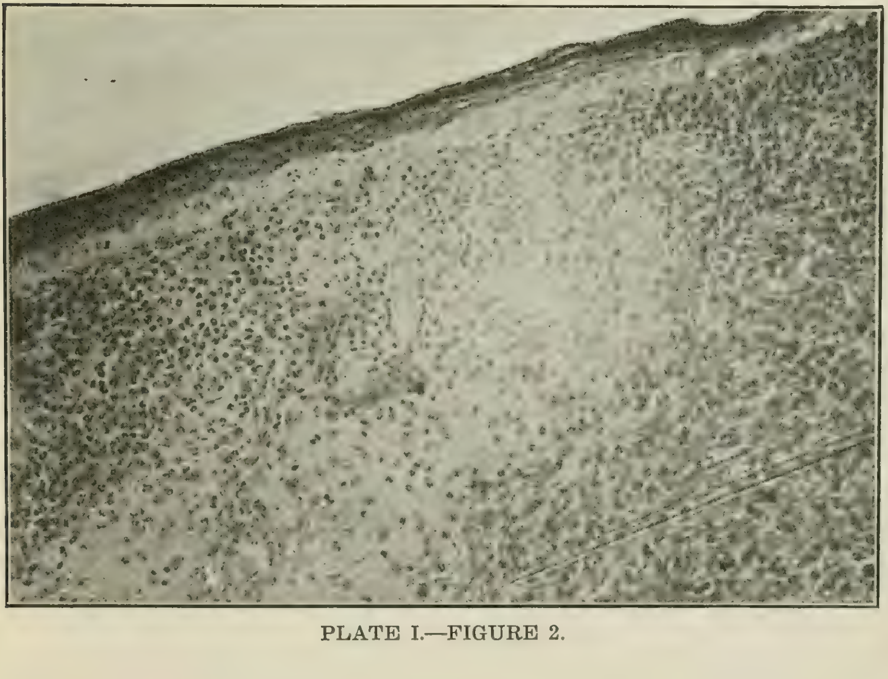


PLATE I.—FIGURE 2.

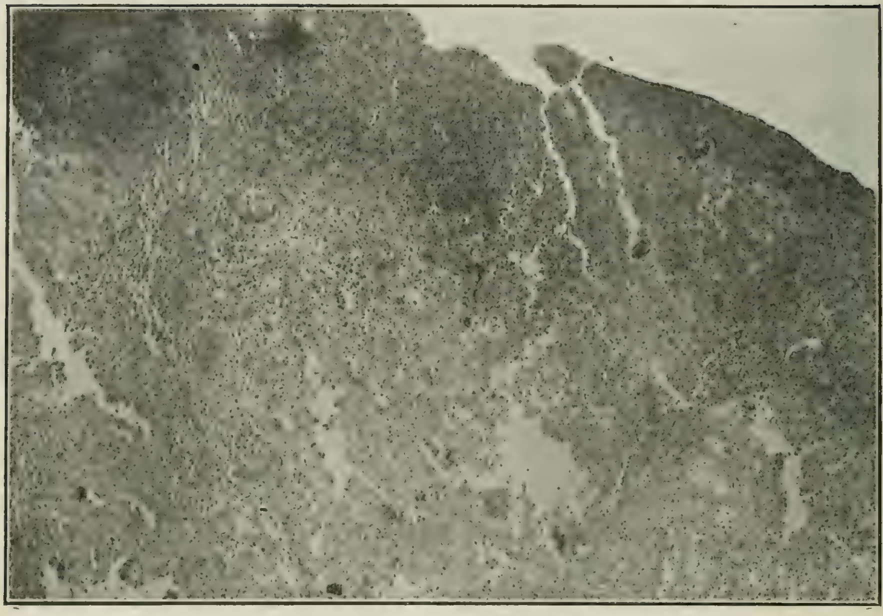


PLATE II.—FIGURE 3.

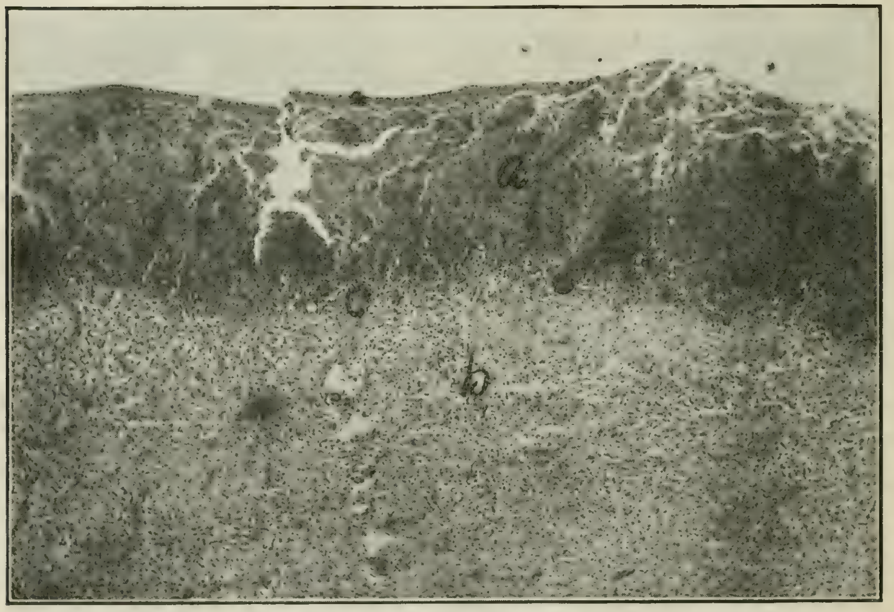


PLATE II.—FIGURE 4.

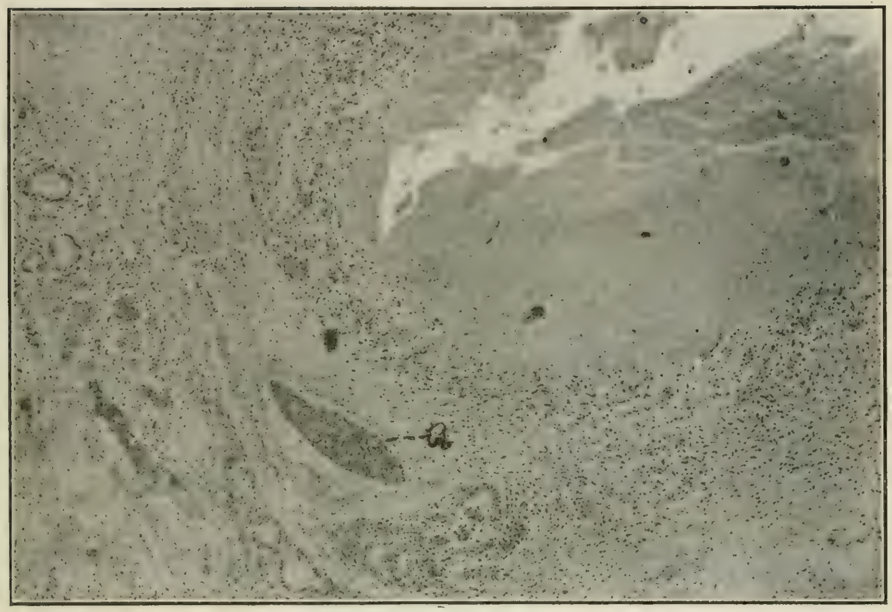


PLATE III.—FIGURE 5.

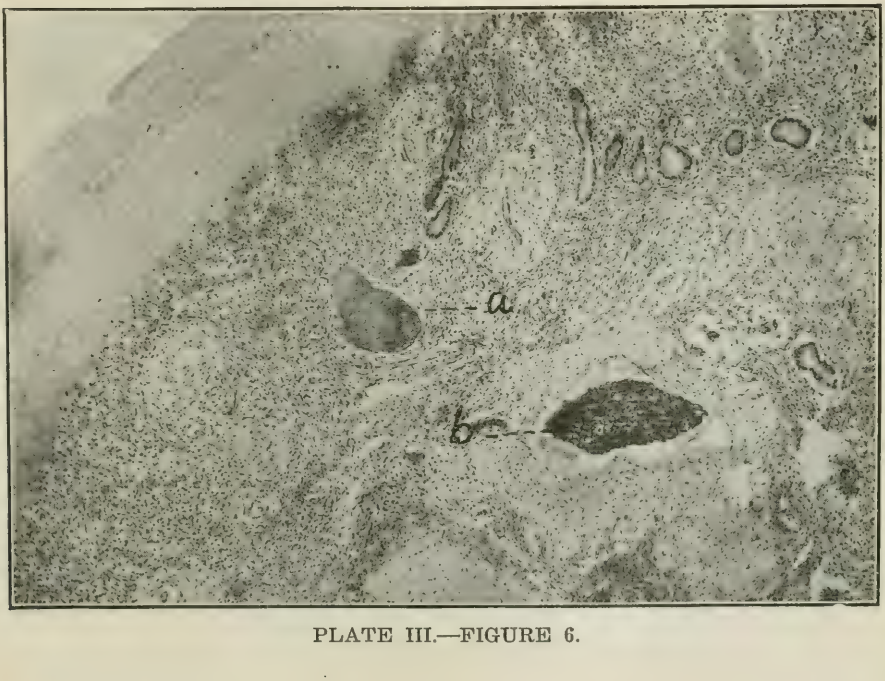


PLATE III.—FIGURE 6.

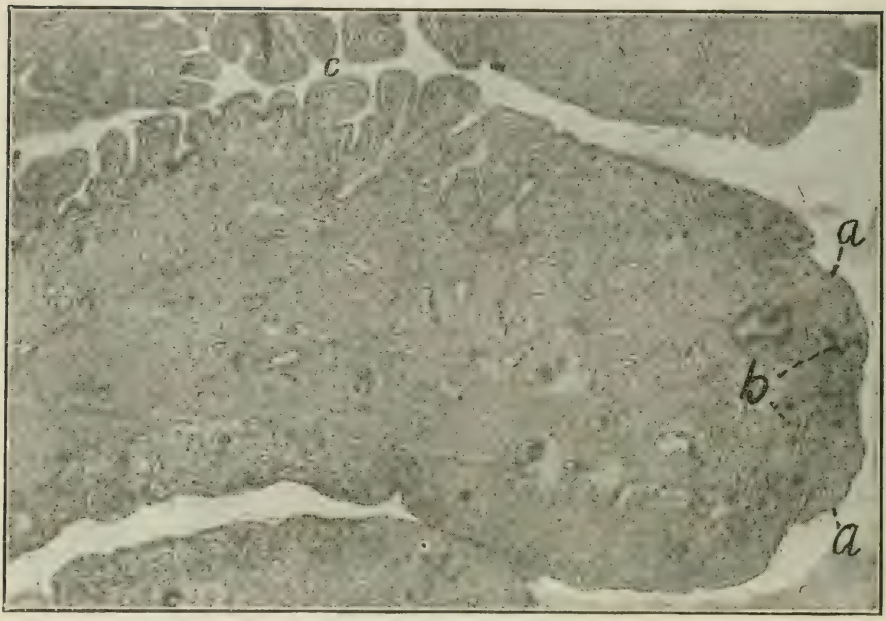


PLATE IV.—FIGURE 7.

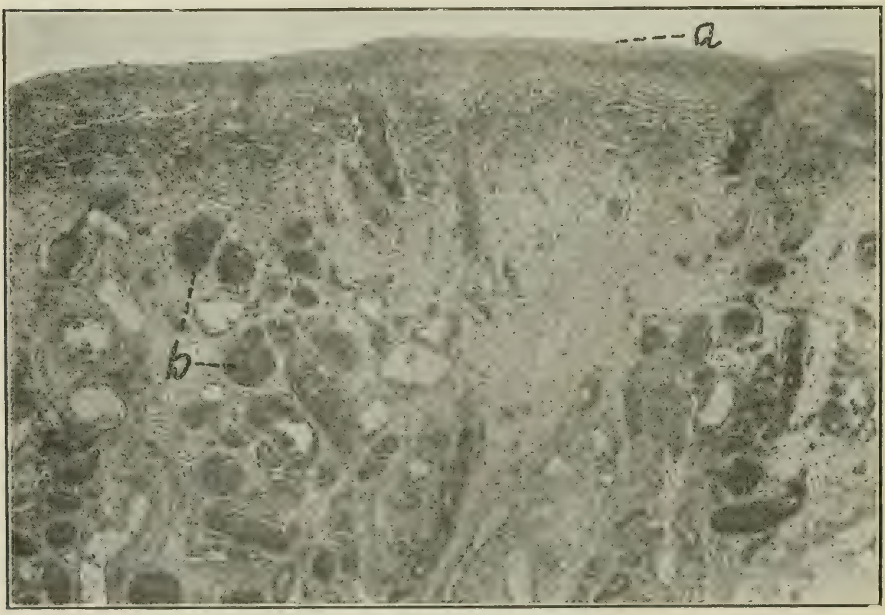


PLATE IV.—FIGURE 8.

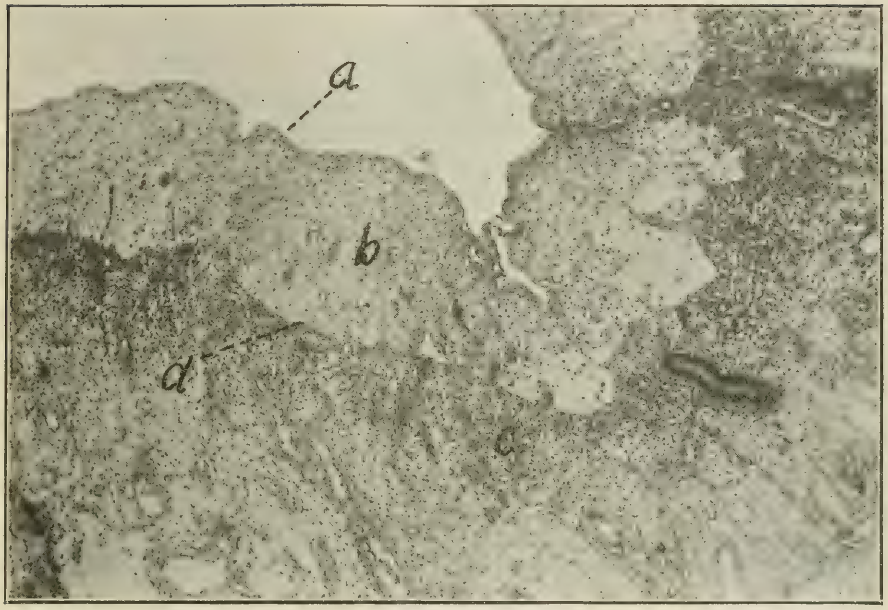


PLATE V.—FIGURE 9.

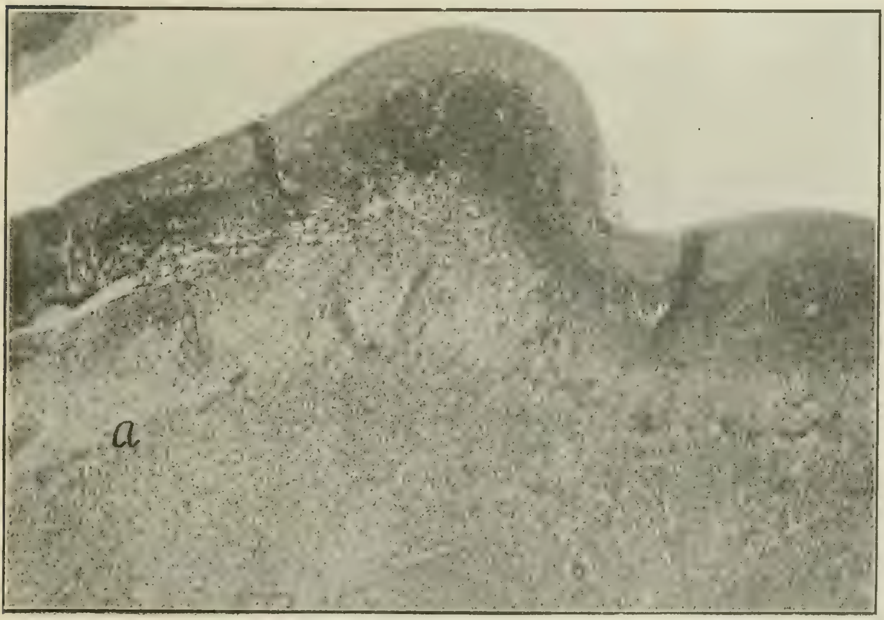


PLATE V.—FIGURE 10.

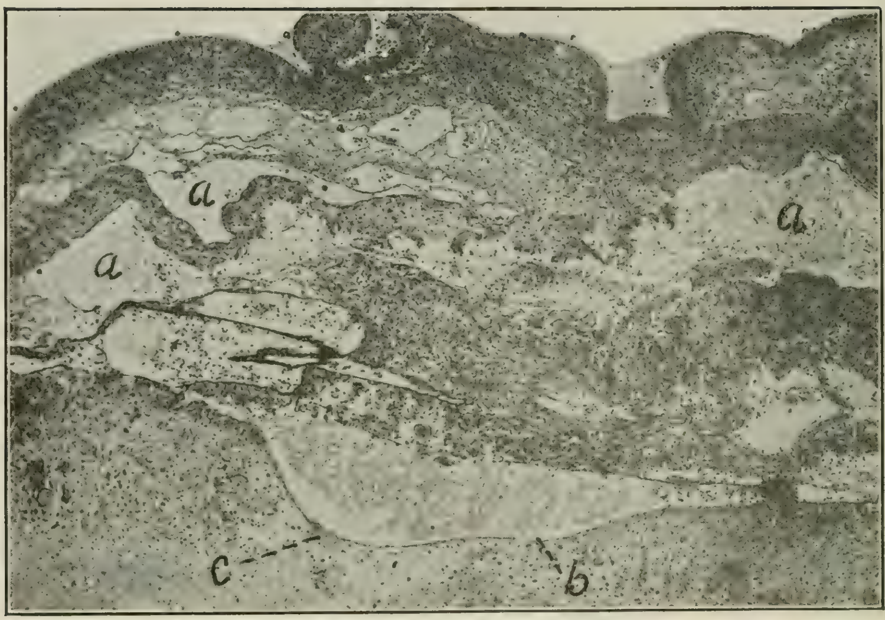


PLATE VI.—FIGURE 11.

PLATE VI.—FIGURE 12.

THE COMPARATIVE PATHOGENICITY OF SEVERAL STRAINS OF BACTERIUM ABORTUS (BANG)

Technical Bulletin No. 55

BY I. FOREST HUDDLESON

Since the isolation and description of *Bact. abortus* by Bang in 1898, a large number of strains have been isolated by various workers in this country and in Europe. No data, however, have appeared which pertain to a study of the pathogenic relationship and an attempt at grouping of the various strains isolated. A study of this nature, if conducted upon suitable animals, should reveal differences in the various strains of *Bact. abortus* as regards the production of characteristic lesions or the symptom of abortion (premature expulsion of the fetus). The above pathogenic properties of *Bact. abortus* need no discussion as detailed descriptions and discussions of both have previously appeared in publications.

It is a well known fact that individual members of a species of a microorganism may be so related that it is impossible to differentiate or group them as to their pathogenic properties by studying their morphological, cultural and biochemical characteristics. Such a differentiation of individual strains may be made possible if their pathogenic properties are studied *in vivo*. In other words, pathogenic and non-pathogenic, and intermediate strains may be distinguished. Further, a loss of virulence as a result of long cultivation upon an artificial medium may be discovered by studying the pathogenic properties of each individual strain.

The importance of a knowledge of the pathogenic properties of strains of *Bact. abortus* becomes obvious when one desires to produce, experimentally, abortion in pregnant animals, or to determine the efficacy of various prophylactic and therapeutic measures in controlling the disease.

A preliminary experiment was begun in the fall of 1916 to determine if there was a difference in several strains of *Bact. abortus* as regards their ability to produce lesions in the organs of guinea pigs following inoculation. Several of the cultures used were isolated from material received at this laboratory, and several were received from other laboratories. The experiment was not completed at this time for various reasons, but the data collected indicated that there was sufficient difference to warrant further study. In January, 1920, the problem was again taken up for further study with the same strains and additional strains.

METHOD OF STUDY

The guinea pig was used for these studies as its high degree of susceptibility toward *Bact. abortus* as regards characteristic tissue changes had been demonstrated in previous experiments. In order to produce these changes it is necessary that the inoculum consist of the optimum number of living organisms. The dosage should not be too large. The writer has confirmed the observation of Fabyan (1) that a large percentage of pigs will develop various complications in less than ten days after too heavy an inoculation, which usually terminates in death before macroscopic changes appear in the spleen and liver.

Following the inoculations, sufficient time was permitted to elapse for the development of characteristic lesions in the spleen and liver of the pigs. An autopsy was then made, all anatomical changes were noted, all spleens and livers were cultured for the presence of *Bact. abortus* and a blood sample was taken for determining the presence of complement-fixing and agglutinating antibodies for *Bact. abortus.*

Inoculation. A loopful of each culture was planted into tubes of liver infusion broth (pH. 6.6) and incubated at 37° for forty-eight hours. One-half cubic centimeter of the broth culture was inoculated intra-abdominally into each of two guinea pigs ranging from 300 to 600 grams in weight. The pigs were placed in cages after inoculation and observed for a period of approximately twelve weeks.

Autopsy. At the end of the foregoing period the pigs were chloroformed and the abdominal and thoracic cavaties exposed, and all anatomical changes occurring in the organs noted.

Bacteriological Examination. Small bits of tissue from suspicious lesions, and from the spleen and liver of each pig were streaked over the surface of a liver agar (pH. 6.6) plate. The plates were placed in jars in which 10 per cent of the air was replaced by CO_2 gas, sealed and then incubated at 37° C for three days. The presence or absence of colonies of *Bact. abortus* was noted in each case.

Complement-Fixation Test. The antigen for the test was prepared by growing several strains of *Bact. abortus* on liver agar for forty-eight hours. The growth was then removed with sterile physiological salt solution to which had been added 0.5 per cent phenol, and shaken mechanically for four hours. The turbidity of the suspension was standardized to tube three of the McFarland (2) nephelometer and titrated for its anticomplementary dose. The unit used in the test was usually one-third of the anticomplementary unit.

All sera were inactivated in the water-bath at 56° C for one-half hour and used in amounts of 0.1, 0.04, 0.02, and 0.005 c. c., and a fifth control tube of 0.1 c. c.

The tests were conducted with the sheep-rabbit hemolytic system using two units of hemolysin and 0.5 c. c. of a 2 per cent suspension of sheep cells in all titrations.

The first and second incubations were conducted in the water-bath at 37° C for one-half hour. At the end of the second incubation the results were recorded as positive in tubes showing no hemolysis, partial in tubes showing any degree of hemolysis and negative in tubes showing complete hemolysis.

Agglutination Test. The antigen for the agglutination test was prepared by growing several strains of *Bact. abortus* on liver agar for forty-eight hours, removing the growth with sterile physiological salt solution to which was added 0.5 per cent phenol, mechanically shaking for four hours and then standardizing to a turbidity of three of the McFarland (2) nephelometer. It might be mentioned here that the turbidity of the antigen is a very important factor in the agglutination test. An antigen of a turbidity less than three is very unsatisfactory owing to the occurrence of "pro-agglutination".

In the tests, two cubic centimeters of antigen were placed in each of four small test tubes and the following quantities of serum added: 0.05, 0.025, 0.01, 0.005 c. c. The tubes were incubated either at 56° C for two hours in the water-bath or in a dry incubator at 37° C for twelve hours. The final results were practically the same for both methods of incubation. The results were recorded as positive in complete clumping of the antigen, partial when the supernatent liquid was not entirely clear and negative in the absence of clumping.

HISTORY OF STRAINS

Each culture of *Bact. abortus* employed in these studies except Strain 1, has on some previous occasion, produced characteristic lesions and enlarged spleen in inoculated guinea pigs. The date of isolation and origin of Strain 1 is not known, nor is there a past record which shows that it was at one time virulent. The two strains, No. 1 swine and 2010, isolated from fetuses of aborting swine are indistinguishable from *Bact. abortus*, Bang. The dates of the isolation of the English and German strains are not known. The former English strain was obtained from the Royal Veterinary College in England and the German strain from Dr. Oldt of Berlin. When the two strains were first brought to this country they produced pronounced lesions in guinea pigs. *Bact. melitensis* 1 has no history of ever being virulent. *Bact. melitensis* 22 was classed as non-virulent, *Bact. melitensis* 27 as virulent by Dr. K. F. Meyer of the University of California.

RECORDS AND RESULTS

As shown in Table II, the first comparative study was conducted in January, 1920, using twelve strains of *Bact. abortus* which were isolated from aborted fetuses or naturally infected milk from cattle. The second study was conducted in April, 1921, and the third in August, 1921. There were altogether twenty-one strains included in the second and third studies, twelve strains of which were employed in the first study. The three strains of *Bact. melitensis* were introduced into the study for the purpose of comparing their lesion-producing properties with those of *Bact. abortus*.

In Table II, it is clearly shown that of the first twelve strains employed; five (1, 2, 3, 805 and 16) did not produce lesions in the first inoculation series, nine (1, 2, 3, 805, J, E, C, Germany and England) did not in the second series; and ten (1, 2, 3, 805, 7, 16, J, E, Germany and England) did not in the third series. Strain 16 appeared non-virulent in the first series, virulent in the second and non-virulent again in the third series of inoculations. Strain C, appeared virulent in the first series, non-virulent in the second and virulent again in the third series. There were four strains, as indicated above, which proved to be non-virulent in all three series of inoculations. Of the nine strains added in the second series of inoculations, two (Strains No. 1 Swine and W) appeared to be non-virulent in the second series of inoculations, and four of the nine (Strains No. 1 Swine, W, 2010, and 100) appeared non-virulent in the third series of inoculations. There were two of the nine strains, as indicated above, which proved to be non-virulent in both series of inoculations. There were altogether five strains which failed to produce lesions in guinea pigs throughout the studies. The strains were 1, 2, 3, 805, No. 1 Swine and W. Only one strain, 6, produced typical lesions and enlarged spleens in all three successive series of inoculations, and only seven of the total twenty-one strains appeared to show any degree of virulence in the last series of inoculations.

Bact. melitensis 1 and 22 failed to produce lesions on all series of inoculations. *Bact. melitensis* 27, produced lesions in duplicate pigs consistently. Cultural findings were negative in pigs receiving injections of Strains 1 and 22 (melitensis), and positive in pigs receiving Strain 27 (melitensis) only. None of the guinea pigs inoculated with *Bact. melitensis* 22 developed serum agglutinins or complement-fixing antibodies for *Bact. abortus*. Guinea pigs receiving *Bact. melitensis* 27 developed serum complement-fixing antibodies for *Bact. abortus* to a marked degree, but very little agglutinins. The sera of the inoculated pigs were not titered against an antigen made from *Bact. melitensis.*

Table III shows the comparative weights of the pigs before inoculation (April 29, 1921) and before autopsy (July 25, 1921). Pigs showing lesions from the inoculation of Strains 6, 7, 16, 20, 200 and L decreased in weight from ten to one hundred grams. Those showing the presence of lesions from the inoculation of Strains 22 and 100 increased in weight. In all pigs showing the absence of lesions from inoculation there was a marked increase in weight.

Of the twelve original strains studied, four consistently failed to produce lesions in guinea pigs on inoculation. These findings indicate that their virulence had disappeared in so far as producing tissue changes in the guinea pig are concerned. Six strains became non-virulent during these studies, and two gave inconsistent results. Of the nine new strains added in the second series of inoculations four became non-virulent. Altogether, ten strains became non-virulent before the series of studies were completed. Of all the strains studied number 6 appears to be the most interesting as regards lesion production in guinea pigs. This strain is perhaps the oldest in the laboratory, yet in contrast with the other strains studied it has consistently produced characteristic lesions in the spleen of guinea pigs on inoculation. Table II, clearly shows that the gross changes occurring in the spleens of pigs autopsied in November, 1921, were not so extensive as those occurring in pigs inoculated with the same strains and autopsied in July, 1921. One might infer from these results that there are many more of the strains gradually losing their virulent properties.

The tissue changes produced in guinea pigs by virulent strains of *Bact. melintensis* cannot be distinguished from those changes produced by virulent strains of *Bact. abortus. Bact. melitensis* 27, stimulated the production of antibodies for *Bact. abortus* in the serum of the guinea pig to a high degree. Strains 1 and 22 (melitensis) stimulated very little antibody production for *Bact. abortus.* The difference in antibody production is probably due to the group difference of the strains of *Bact. melitensis.* The grouping of *Bact. melitensis* and the relations of the various groups to *Bact. abortus* has been clearly demonstrated by Fusier and Meyer (3).

It was found that as a general rule the cultural findings agreed with the presence of lesions and enlarged spleens. In other words, whenever characteristic lesions were present, *Bact. abortus* was also present. In the absence of lesions or enlarged spleens *Bact. abortus* could not be found.

It is interesting to note in Table II, that there was a marked decline in serum agglutinins and complement-fixing bodies in pigs showing no enlarged spleen or lesions. In fact the blood serum of several of these pigs was negative to one or both tests at the time of autopsy; while in pigs showing characteristic lesions the antibody content of the blood serum, as indicated by the serological tests, was as a rule, very high. These negative findings indicate that many strains of *Bact. abortus* possess very low invasive properties. It is possible that those strains may have invaded the tissues shortly after inoculation, and could have been isolated therefrom if cultured at that time.

It was noted in this study that many guinea pigs showed a marked variable susceptibility toward *Bact. abortus.* For example, occasionally one pig of a duplicate would show an acute diarrhea and become extremely emaciated in less than five days after inoculation, and succumb shortly after the appearance of symptoms. The anatomical changes noted in such cases were a fibrinous peritonitis or a pleuro-pneumonia. Occasionally inoculated pigs show paralysis of the hind parts or enlarged joints.

The apparent failure of Strains 16 and C (abortus) to produce lesions in guinea pigs in each series of inoculations may be explained from the fact that individual pigs are refractory to *Bact. abortus* infections. The variable susceptibility of guinea pigs to infection renders one inoculation test inconclusive in attempting to classify virulent and non-virulent strains of *Bact. abortus* by this procedure.

It is clearly shown in Table III that there was a decrease in the weight of pigs inoculated with strains of *Bact. abortus* which had not lost their lesion-producing property. There were, however, exceptions to this rule which are difficult to explain. In not a single case was there a decrease in the weight of pigs which showed the absence of lesions. The failure of pigs to lose weight cannot always be accepted as a criterion of non-invasion by *Bact. abortus.*

While these studies have not lead to a definite grouping of strains of *Bact. abortus* as regards lesion production, they have, however, demonstrated conclusively that there exist many strains which will not produce characteristic lesions in the organs of guinea pigs on inoculation. The lack of this property is undoubtedly not inherent, but results from long cultivation upon an artificial medium. The gradual loss of the lesion-producing property is demonstrated in these studies. The loss of this property may be transitory and it may be restored when the organism is placed in a more natural medium. This point, however, should be given further study before it is fully discussed.

The foregoing results certainly demonstrate the fallacy of undertaking infection experiments with cultures of *Bact. abortus* without a knowledge of the present virulence of the strains employed.

SUMMARY AND CONCLUSIONS

1. These studies show that a large number of strains of *Bact. abortus,* after several generations of cultivation on an artificial medium, lose the property of producing lesions in the organs of guinea pigs on inoculation. A majority of the strains isolated became non-virulent within one year after isolation.
2. The cultural findings agreed with the presence or absence of lesions, that is, when characteristic lesions were found in the organs of the guinea pig *Bact. abortus* was also present, *Bact. abortus* was not found in the absence of lesions.
3. The agglutination and complement fixation antibody indices of the blood sera were low in pigs showing no lesions and high in pigs showing lesions.
4. There was a marked decrease in weight of the majority of the pigs showing lesions and an increase in weight in those showing no lesions.
5. The results of this study indicate that there is in existence a large number of non-virulent strains of *Bact. abortus.*

6. Before one undertakes experiments to induce abortion in cattle, swine, sheep, etc., or to determine the efficacy of various prophylactic agents such as anti-serums, vaccines and chemicals, it is fundamental that the virulence of the strain of *Bact. abortus* employed should be determined by such means as guinea-pig inoculations.

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3. Feusier, M. S., and Meyer, K. F. Principles in serologic groupings of *B. abortus* and *B. melitensis*. Corrulation between absorption and agglutination tests: Studies on the genus *Brucella*, Nov. Gen. II, 1920. Jour. Infectious Disease, Vol. 27, No. 3, P. 185.

Table No. I—Showing the Autopsy and Cultural Findings and Results of Blood Tests

Strain	Date of Inoculation	Date of Autopsy	Autopsy Findings	Cultural Findings	Blood Tests	
					Aggl.	Comp. Fix
1	1–12–20	4–30–20	All organs app. normal.	B. abortus negative	− − − −	+ + + −
1	“	“	“ “ “ “	“ “	+ + + +	+ + + +
1	4–29–21	7–25–21	“ “ “ “	“ “	− − − −	− − − −
1	“	“	“ “ “ “	“ “	− − − −	− − − −
1	8–10–21	D-17-21	“ “ “ “	“ “	+P − −	+ + + −
1	“	“	“ “ “ “	“ “	− − − −	+ + + +
2	1–12–20	4–30–20	“ “ “ “	“ “	+ +P −	+ + + +
2	“	“	....	....	....	....
2	4–29–21	Died 6–25–21	....	....	....	....
2	“	7–25–21	All organs app. normal.	B. abortus negative	+ + + +	+ + + +
2	8–10–21	11–17–21	“ “ “ “	“ “	+ + + +	+ + + +
2	“	“	“ “ “ “	“ “	+ + + +	+ + + +
3	1–12–20	4–30–20	“ “ “ “	“ “	+ + + +	+ + + +
3	“	“	“ “ “ “	“ “	+ + + +	+ + + +
3	4–29–21	7–25–21	“ “ “ “	“ “	− − − −	+ + + −
3	“	“	“ “ “ “	“ “	Lost	....
3	8–10–21	11–17–21	“ “ “ “	“ “	− − − −	+ − − − −
3	“	“	“ “ “ “	“ “	+ − − −	+ + + −
6	1–12–20	Lost	....	....	....	....
6	“	Lost	....	....	....	....
6	4–29–21	7–25–21	Abscess in left testicle. Spleen enlarged 5 times..............	B. abortus positive	+ + + +	+ + + +
6	“	“	Foci in lungs spleen enlarged 3 times.....	“ “	+ + + +	+ + + +
6	8–10–21	D-17-21	Spleen enlarged 5 times.	Plates contaminated.........	+ + + +	+ + + +
6	8–10–21	11–17–21	Spleen enlarged 5 times.	B. abortus positive	+ + + +	+ + + +
7	1–12–20	Lost	....	....	....	....
7	“	4–30–20	Spleen slightly enlarged	B. abortus positive	+ + + +	+ + + +
7	4–29–21	7–25–21	Lungs showed lesions...	“ “	+P − −	+ + + +
7	5–16–21	“	“ “ “	“ “	+ + + −	+ + + +
7	8–10–21	11–17–21	All organs app. normal.	B. abortus negative	+ + + +	+ + + +
7	“	“	“ “ “ “	“ “	− − − −	+ + + −
16	1–12–20	4–30–20	“ “ “ “	“ “	+ + + +	+ + + +
16	“	“	“ “ “ “	“ “	+ + + +	+ + + +
16	4–29–21	7–25–21	Spleen enlarged 10 times..............	B. abortus positive	+ + + +	+ + + +
16	4–29–21	Killed 6–16–21	Spleen enlarged 3 times.	“ “	Lost	....
16	8–10–21	11–17–21	All organs app. normal.	B. abortus negative	+ + + +	+ + + +
20	1–12–20	Lost	....	....	....	....

Table No. 1—Con't.—Showing the Autopsy and Cultural Findings and Results of Blood Tests

Strain	Date of Inoculation	Date of Autopsy	Autopsy Findings	Cultural Findings	Blood Tests	
					Aggl.	Comp. Fix.
20	1–12–20	Lost	....	....	....	....
20	4–29–21	Killed 5–16–21	Lesions in lungs. Spleen enlarged 3 times.....	B. abortus positive	Lost	....
20	“	7–25–21	Spleen enlarged 5 times.	“ “	++++	++++
20	8–10–21	11–17–21	Spleen enlarged 5 times.	“ “	++++	++++
20	8–10–21	“	Paralysis of hind parts. Spleen enlarged 3 times.	“ “	++++	++++
J	1–12–20	4–30–20	Spleen slightly enlarged	B. abortus negative	++++	++++
J	“	“	All organs app. normal.	“ “	+++−	++++
J	4–29–21	7–26–21	All organs app. normal.	B. abortus negative	++++	++++
J	“	“	“ “ “ “	“ “	++−−	++++
J	8–10–21	11–17–21	“ “ “ “	“ “	++++	++++
J	“	“	“ “ “ “	“ “	++++	++++
E	1–12–20	4–30–20	Spleen slightly enlarged	B. abortus positive	++++	++++
E	“	“	Foci in liver. Spleen app. normal........	B. abortus negative	+++−	++++
E	4–29–21	7–26–21	All organs app. normal.	“ “	++++	++++
E	“	“	“ “ “ “	“ “	−−−−	+−−−
E	8–10–21	11–17–21	“ “ “ “	“ “	−−−−	−−−−
E	“	“	“ “ “ “	“ “	++P−	+++−
Germany	1–12–20	Lost	....	....	....	....
Germany	“	4–30–20	Spleen slightly enlarged	B. abortus positive	++++	++++
Germany	4–29–21	7–29–21	All organs app. normal.	B. abortus negative	++++	++++
Germany	“	“	“ “ “ “	“ “	++++	++++
Germany	8–10–21	11–17–21	All organs app. normal.	B. abortus negative	++−−	++−−
Germany	“	“	“ “ “ “	“ “	−−−−	++−−
22	1–12–20	4–30–20	Foci in liver and spleen. Spleen enlarged 3 times.	B. abortus positive	++++	++++
22	“	“	Spleen enlarged 3 times.	“ “	−−−−	++++
22	4–29–21	Died 5–16–21	Lesions in both lungs. Spleen enlarged 3 times.	“ “	+++−	++++
22	“	7–25–21	Spleen enlarged 3 times.	“ “	++++	++++
22	8–10–21	11–17–21	Spleen enlarged slightly	B. abortus negative	++++	++++
22	“	“	Spleen enlarged slightly	“ “	++++	++++
805	1–12–20	4–30–20	All organs app. normal.	“ “	++−−	++++
805	1–12–20	4–30–20	All organs app. normal.	B. abortus negative	++++	++++
805	4–29–21	7–25–21	“ “ “ “	“ “	++++	++++
805	“	“	“ “ “ “	“ “	+P−−	++++
805	8–10–21	11–17–21	“ “ “ “	“ “	++++	++++
805	“	“	“ “ “ “	“ “	++++	++++
C	1–12–20	4–30–20	Spleen enlarged 3 times.	B. abortus positive	+++−	++++
C	“	“	Spleen enlarged 3 times.	“ “	++++	++++

Table No. 1 Con't.—Showing the Autopsy and Cultural Findings and Results of Blood Tests

Strain	Date of Inoculation	Date of Autopsy	Autopsy Findings	Cultural Findings	Blood Tests	
					Aggl.	Comp. Fix.
C	4–29–21	7–26–21	All organs app. normal	B. abortus negative	+ + + +	+ + + +
C	“	“	“ “ “ “	“ “	+ + + P	+ + + +
C	8–10–21	11–17–21	Spleen slightly enlarged	B. abortus positive	+ + + +	+ + + +
C	“	“	Spleen slightly enlarged	“ “	+ + + +	+ + + +
W	1–12–20	Lost	....	....	....	....
W	“	“	....	....	....	....
W	4–29–21	7–26–21	All organs app. normal.	B. abortus negative	+ + P –	+ + + +
W	“	“	“ “ “ “	“ “	P – – –	+ + + +
W	8–10–21	11–15–21	“ “ “ “	“ “	– – – –	+ + + –
W	“	“	“ “ “ “	“ “	+ – – –	+ + – –
England	1–12–20	4–30–20	Spleen enlarged 5 times.	B. abortus positive	+ + P –	+ + + +
England	“	“	Spleen enlarged 5 times.	“ “	– – – –	+ + + +
England	4–29–21	7–26–21	All organs app. normal.	B. abortus negative	– – – –	– – – –
England	“	“	“ “ “ “	“ “	+ + + +	+ + + +
England	8–10–21	11–17–21	“ “ “ “	“ “	+ + + +	+ + + +
England	“	“	“ “ “ “	“ “	+ + + +	+ + + +
60	4–29–21	7–25–21	Spleen enlarged 3 times.	B. abortus positive	+ + + P	+ + + +
60	“	“	“ “ “ “	“ “	+ + + +	+ + + +
60	8–10–21	11–17–21	Spleen enlarged 2 times.	B. abortus positive	+ + + +	+ + + +
60	“	“	Spleen enlarged 4 times.	“ “	+ + + +	+ + + +
100	4–29–21	7–20–21	Spleen enlarged 4 times.	“ “	+ + + +	+ + + +
100	“	“	Spleen enlarged 4 times.	“ “	+ + + +	+ + + +
100	8–10–21	11–17–21	All organs app. normal.	B. abortus negative	+ + + +	+ + + +
100	“	“	“ “ “ “	“ “	+ + + +	+ + + +
200	4–29–21	7–26–21	Spleen enlarged 3 times.	B. abortus positive	+ + + –	+ + + +
200	“	“	Spleen enlarged 8 times.	“ “	+ + + +	+ + + +
200	8–10–21	11–17–21	Spleen slightly enlarged	“ “	+ + + +	+ + + +
200	“	“	“ “ “ “	“ “	+ + + +	+ + + +
L	4–19–21	7–26–21	Spleen enlarged 5 times.	B. abortus positive	– P + +	+ + + +
L	“	“	All organs normal.....	B. abortus negative	+ – – –	+ + + ÷
L	8–10–21	11–17–21	Spleen slightly enlarged	B. abortus positive	+ + + +	+ + + +
L	“	“	Spleen enlarged 3 times.	“ “	+ + + +	+ + + +
No. 1 Swine	4–29–21	7–26–21	All organs app. normal.	B. abortus negative	+ + – –	+ + + +
No. 1 Swine	“	“	“ “ “ “	“ “	+ + + –	+ + + +
No. 1 Swine	8–10–21	11–17–21	“ “ “ “	“ “	– – – –	+ P – –
No. 1 Swine	“	“	“ “ “ “	“ “	– – – –	+ + + +
Swine 2010	4–29–21	Died 6–25–21	....	....	....	....
2010	“	7–26–21	Spleen enlarged 2 times.	B. abortus positive	+ + + +	+ + + +

Table No. 1 Con't.—Showing the Autopsy and Cultural Findings and Results of Blood Tests

Strain	Date of Inoculation	Date of Autopsy	Autopsy Findings	Cultural Findings	Blood Tests	
					Aggl.	Comp. Fix.
2010	8–10–21	11–17–21	All organs app. normal.	B. abortus negative	++++	++++
No. 1 Melitensis	4–29–21	7–26–21	All organs app. normal.	B. Melitensis negative	----	----
No. 1 Melitensis	“	“	“ “ “ “	“ “	+P--	++++
No. 1 Melitensis	8–10–21	11–17–21	“ “ “ “	“ “	----	+++-
No. 1 Melitensis	“	“	“ “ “ “	“ “	----	++--
No. 27 Melitensis Gr. II	5–19–21	8–4–21	Spleen enlarged 3 times.	B. Melitensis positive	+++-	++++
No. 27 Melitensis Gr. II	“	“	Spleen enlarged 3 times.	“ “	++++	++++
No. 27 Melitensis Gr. II	8–10–21	11–17–21	Spleen enlarged 3 times.	“ “	----	++++
No. 27 Melitensis Gr. II	“	“	Spleen enlarged 3 times.	“ “	----	++++
No. 22 Melitensis Gr. 4	5–19–21	8–4–21	All organs app. normal.	B. Melitensis negative	----	----
No. 22 Melitensis Gr. 4	“	“	“ “ “ “	“ “	----	----
No. 22 Melitensis Gr. 4	8–10–21	11–17–21	“ “ “ “	“ “	----	----
No. 22 Melitensis Gr. 4	“	“	“ “ “ “	“ “	----	----

+	Indicates positive reaction in 0.1 c. c. of serum in complement fixation test.
++	“ “ “ “ 0.04 “ “ “ “ “ “ “
+++	“ “ “ “ 0.02 “ “ “ “ “ “ “
++++	“ “ “ “ 0.005 “ “ “ “ “ “ “
+	Indicates positive reaction in 0.05 c. c. of serum in the agglutination test.
++	“ “ “ “ 0.025 “ “ “ “ “ “
+++	“ “ “ “ 0.01 “ “ “ “ “ “
++++	“ “ “ “ 0.005 “ “ “ “ “ “

Table No. II—Showing History of Strains of Bact. Abortus Employed in the Comparative Studies

Strain	Date of Isolation	Origin
I	Unknown.........	Received from Bureau of Animal Industry prior to 1915.
2	1915.............	Aborted fetus (From Herd A).
3	1915.............	" " " "
6	1915.............	Udder of Cow 995 (Abortion Experimental Herd).
7	Unknown.........	In laboratory prior to 1916.
16	June, 1917........	Aborted fetus, Owosso, Michigan.
20	May, 1919........	Placenta of Cow following abortion, Ubly, Michigan.
22	September, 1919...	Aborted fetus (From Herd A).
805	May, 1919........	Placenta of Cow 805 following abortion (Abortion Experimental Herd).
C	March, 1917......	Aborted fetus (From Herd A).
W	Unknown.........	Received from Wisconsin University, 1915.
J	1916.............	Aborted fetus (From Herd B).
E	Prior to 1916.....	Unknown.
Germany	Unknown.........	Obtained in Germany in May, 1919.
England	"	Royal Veterinary College, April, 1919.
60	February, 1920....	Udder of Cow (From Herd A).
100	June, 1920........	Udder of Cow No. 100 (Abortion Experimental Herd).
200	January, 1920.....	Udder of Cow No. 200 (Abortion Experimental Herd).
L	December, 1920...	Aborted fetus (From Herd A).
No. 1 Swine	March, 1920......	Aborted fetus of sow near Lansing, Michigan.
No. 2010 Swine	Received 9/3/20...	Dr. Graham, Illinois University.
No. 1 Melitensis	Received 1/19/20..	American Museum of Natural History.
Group II Melitensis	Received 5/15/21..	Doctor Meyer, University of California.
Group IV Melitensis	Received 5/15/21..	Doctor Meyer, University of California.

Table No. III—Showing Comparative Weights of Guinea Pigs Before Inoculation and Before Autopsy. Pigs Inoculated April 29, 1921

Strain	Weight before Inoculation	Weight before Autopsy	Lesions
1	615 gms.	805 gms.	Negative
1	530 “	675 “	“
2	585 “	705 “	“
3	590 “	755 “	“
3	690 “	700 “	“
6	605 “	445 “	Positive
6	505 “	495 “	“
7	485 “	450 “	“
7	560 “	490 “	“
16	645 “	555 “	“
16	535 “	410 “	“
20	465 “	380 “	“
20	695 “	440 “	“
22	385 “	470 “	“
60	390 “	470 “	“
60	250 “	290 “	“
805	645 “	690 “	Negative
805	468 “	570 “	“
100	490 “	550 “	Positive
100	425 “	570 “	“
200	470 “	440 “	“
200	410 “	500 “	“
C	300 “	470 “	Negative
C	240 gms.	470 gms.	Negative
No. 1 Swine	360 “	610 “	“
No. 1 Swine	300 “	550 “	“
L	345 “	300 “	Positive
L	255 “	580 “	“
2010	465 “	510 “	Negative
W	420 “	660 “	“
W	415 “	580 “	“
Germany	355 “	450 “	“
Germany	290 “	480 “	“
England	420 “	670 “	“
England	395 “	510 “	“
E	635 “	770 “	“
E	570 “	700 “	“
J	460 “	490 “	“
J	400 “	635 “	“

TECHNICAL BULLETIN NO. 56

FOREWORD

In June 1920, Mr. J. E. Kotila received the degree of Master of Science from the Michigan Agricultural College.

Mr. Kotila selected as a minor a study of the life history of the leafhopper of potato, and the results of this study, together with the results of his subsequent work as a research worker in the Michigan Agricultural Experiment Station, are embodied in the present paper. The evidence gathered during this investigation seems to be of sufficient importance to warrant its publication in this form.

Respectfully submitted,

R. H. PETTIT,
Professor of Entomology.

LEAFHOPPER INJURY TO POTATOES

BY J. E. KOTILA

Leafhopper injury, brought about by the potato leafhopper, has caused losses of thousands of dollars annually to the potato growers of Michigan. Investigations at this and other stations show that it is now possible by the use of preventive measures to reduce largely this source of great loss. The importance of the potato crop in Michigan is such that an effort should be made to combat this injury.

The potato ranks third in importance as an agricultural crop, is surpassed only by hay and corn, and is followed by wheat, oats and fruit. Figures obtained from the 14th U. S. Census Bulletin 1920, compiled below, show the position of Michigan as a potato producing state.

THE POTATO CROP IN VARIOUS STATES

(*From 14th U. S. Census Bulletin 1920)

State	Value	Acreage	Yield
New York	$69,812,321	310,403	32,470,847 bu.
Wisconsin	60,664,851	294,424	26,376,021 bu.
Minnesota	57,383,621	331,930	26,690,056 bu.
Maine	52,339,514	111,378	25,531,470 bu.
Michigan	49,055,600	280,538	23,929,560 bu.
Pennsylvania	47,411,127	233,981	22,051,685 bu.
Colorado	19,524,525	77,337	8,874,783 bu.
California	18,901,258	63,305	8,217,937 bu.
Iowa	10,874,361	97,336	4,438,515 bu.
Nebraska	10,685,998	94,247	4,452,497 bu.

ECONOMIC IMPORTANCE OF SO-CALLED "TIPBURN"

Although the total yield of potatoes in Michigan in the 1919 crop was 23,929,560 bushels, the average yield per acre was only 85 bushels. This low average yield was caused in large part by a very serious dry weather blighting, the so-called "tipburn," which attacked the tips and margins of the leaves (Fig. 1), giving them a burned appearance and causing a premature death of the vines with consequent reduction in yield.

Losses from this trouble have no doubt occurred during all seasons of comparative drought, and especially in seasons with temperature departures above normal, but attention was first called to it in 1891 by Goff[1]. While conducting a potato spraying experiment a peculiar "blighting" of the leaves was noted in the check plots which Goff reported was not the true potato blight, as there were no indications of the fungus *Phytophthora infestans* and no rotting tubers were found when the plots were harvested. Since 1891, however, "tipburn" has been reported as common during hot, dry seasons in all of the more important potato growing states. The trouble was especially severe during the 1919 season and losses up to 25 per cent of the crop were

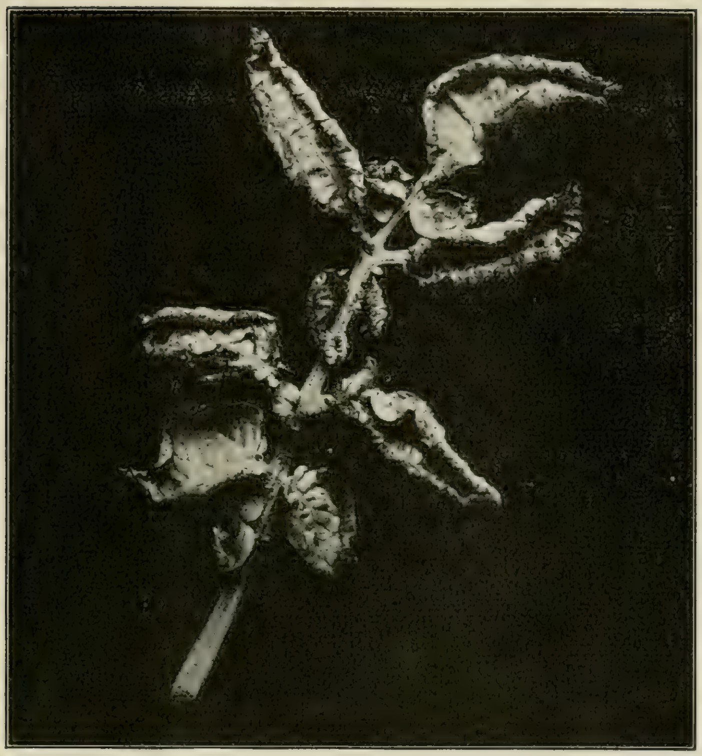

Fig. 1. Potato leaf showing hopperburn. Note the burned effect of tips and margins of leaflets, also the tendency to curl upward

reported to the Plant Disease Survey[2] from various states. The total loss to the United States potato crop in that season was 3.7 per cent or 16,348,000 bushels. The loss to Michigan growers was estimated at 25 per cent or 10,246,000 bushels.

THEORIES AS TO THE CAUSE OF "TIPBURN"

Dry Weather: In 1895 Jones[3] offered a plausible explanation of "tipburn." In contrast to late and early blights, which are of fungous origin, he thought that "tipburn" was "attributable to the unfavorable conditions surrounding the plant, especially dry hot weather, with insufficient water supply." For want of a more satisfactory one this explanation of tipburn has been quoted in practically all potato disease handbooks published since that time.

Lutman[4] in 1919 published data supporting the dry weather theory, in which he states "Tipburn of the potato is due to excessive heat and sunshine during late July and early August. An inordinate transpiration from portions of the leaflets directly affected results in a wilting from which the parts seriously injured do not recover."

It has been repeatedly shown since Goff's[1] trials in 1891 that potatoes sprayed with bordeaux mixture have been comparatively free from "tipburn" injury. There is then a contradiction in the observed facts concerning this burning as is shown by the work of Martin[5], Duggar and Cooley[6], and Lutman[4], who in studying the effect of bordeaux mixture found that the transpiration was greater in sprayed than in unsprayed plants. Another seeming inconsistency of the dry weather theory is found in the Colorado potato regions, where hot, dry weather with very brilliant sunshine is the usual occurrence and where "tipburn" is very rare.

The leafhopper as a causal factor: A more satisfactory explanation of the cause of tipburn and one which eliminated the vagueness embodied in weather effect was offered by Ball[7] in 1918. He attributed the injury to the leafhopper, *Empoasca mali* LeB, having arrived at his conclusion after conducting two cage experiments during one growing season. Ball's findings, however, were so revolutionary in addition to being based upon rather meager experimental data, although well supported by a large amount of field observations, that entomologists and plant pathologists were slow to accept this explanation of the cause of tipburn. The disease being of such significance in Michigan investigations of the cause of the burning of potato foliage were undertaken at the suggestion of G. H. Coons and field experiments with caged plants in the summer of 1919 and greenhouse experiments in the fall of 1919 were undertaken which gave convincing information of the correctness of Balls findings (Kotila[8]). These experiments, as well as those of two other seasons are detailed below.

EXPERIMENTATION

Field experiments were conducted during the 1919, 1920, and 1921 growing seasons at the Upper Peninsula Experiment Station at Chatham, Michigan, in which insect tight cages (Fig. 2) of sufficient size to

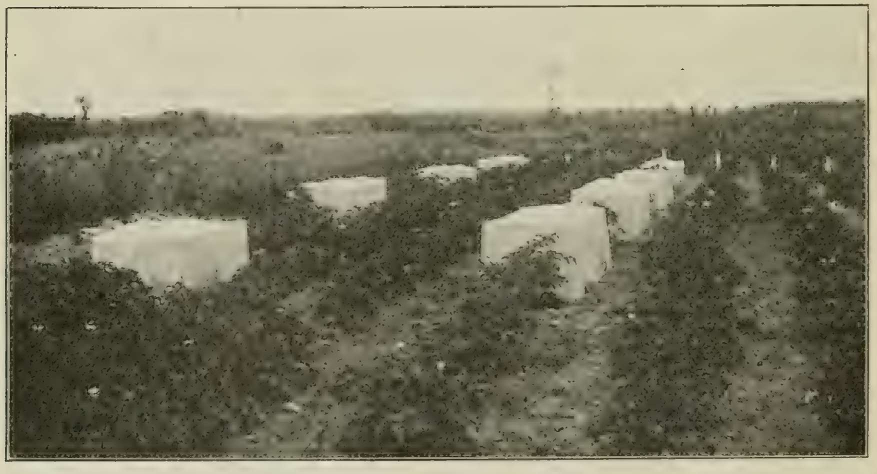

Fig 2. Type of cages used in field experiments.

cover two hills were used. These were set up in the potato rows before the plants had broken through the soil.*

The caged plants remained free from leafhoppers and plant lice (aphids) until these were introduced later in the season. When burning of the foliage became noticeable in the field, leafhopper nymphs and plant lice were placed upon the caged plants. The data obtained during the three seasons are tabulated below:

Table I Effect of the Leafhopper EMPOASCA MALI on Potatoes

Field Experiments - 1919

Planted	Caged*	No. of cages	No. of plants	Treatment	Date	Results	Remarks
July 2	July 9	3	6	25 leaf-hoppers Empoasca mali LeB	Aug. 1	Burning	First signs of injury observed Aug. 4. Leaves showed light-colored margins. Aug. 14 margins of leaves brown. Burned seriously in all 3 cages.
2	9	3	6	Check—no insects	1	No burning.	Leaves normal.
2	9	1	3	25 potato aphids	Sept. 4	No burning.	Leaves green Sept. 25.

Field Experiments - 1920

Planted	Caged*	No. of cages	No. of plants	Treatment	Date	Results	Remarks
June 18	June 30	4	8	25 leaf-hopper nymphs Empoasca mali LeB	Aug. 9	Burning	Characteristic injury to tips and margins of leaves.
18	30	4	8	Check—no insects	9	No burning.	Leaves normal.
18	30	4	8	25 potato aphids	9	No burning.	Leaves remained green all season.

Field Experiments - 1921

Planted	Caged*	No. of cages	No. of plants	Treatment	Date	Results	Remarks
June 11	June 28	3	6	200 leaf-hoppers Empoasca mali LeB	Aug. 11	Burning	Characteristic injury. Tips and margins burned.
11	28	3	6	Check—no insects	11	No burning.	Leaves normal.
11	28	3	6	200 potato aphids	11	No burning.	Leaves green throughout season.

*Cages were set up before plants broke through soil and covered two hills. No insects on plants prior to date leaf-hoppers or plant lice were introduced. 1919 experiments were reported in Phytopath. 10:61-62, 1920.

GREENHOUSE EXPERIMENTS

Unmistakable evidence showing that leafhoppers are capable of causing burning of potato foliage was obtained by experiments conducted in the greenhouse of the Botanical Section of the Michigan Experiment Station, East Lansing, Michigan, during the autumn of 1919 and winter of 1920-21. Adults of the last summer generation were collected and allowed to produce a new generation of nymphs on caged plants (Fig. 3) in the greenhouse, and these were used in the experiments tabulated on following page:

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*Possible criticism might have been offered in Ball's experiments in that the plants were caged late in the season, and complete freedom from "burn" was not maintained in the checks.

Table II Effect of the Leafhopper EMPOASCA MALI on Potatoes
Greenhouse Experiments 1919*

Potted**	Caged	No. of cages	No. of plants	Treatment	Date	Results	Remarks
Sept. 20	At once.	1	3	25 leaf-hoppers......... Empoasca mali LeB....	Sept. 22	Burning....	Leaves showed injury on margins on October 1.
20	At once.	1	3	Check—no insects......	22	No burning.	October 1, leaves green.

*Table reproduced from Kotila 8.
**Sprouted tubers (1919 seed-stock) were potted on this date.

Greenhouse Experiments - 1920-21

Dec. 20	Feb. 17	1	1	30 E. mali nymphs.....	Feb. 17	Burning....	Injury noted February 23.
20	17	1	1	6 E. mali nymphs......	17	Burning....	
20	17	1	1	Check—no insects......	17	No burning.	
20	17	1	1	30 potato aphids.......	17	No burning.	

From the results shown above it was demonstrated that the potato leafhopper, *Empoasca mali*, is capable of producing injury to potato leaves regardless of the season or condition of light, and that aphids do not have a similar effect. The burning produced in cages covered with cheesecloth in the greenhouse during the month of February when the light was very weak as compared to the strength of daylight during

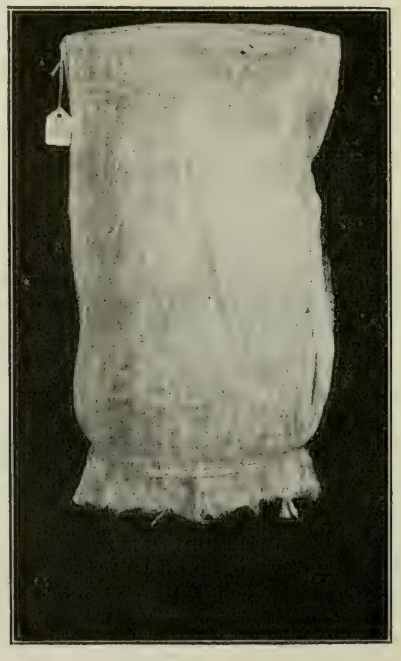

Fig. 3. Type of cage used in greenhouse experiments.

July and August was very typical. (Fig. 4). This production of characteristic signs is of importance since Lutman[4], who ascribes tipburn to excessive heat and sunshine, was unable to produce artificial burning in a greenhouse during the month of April and attributed his failure to weakness of daylight during that month.

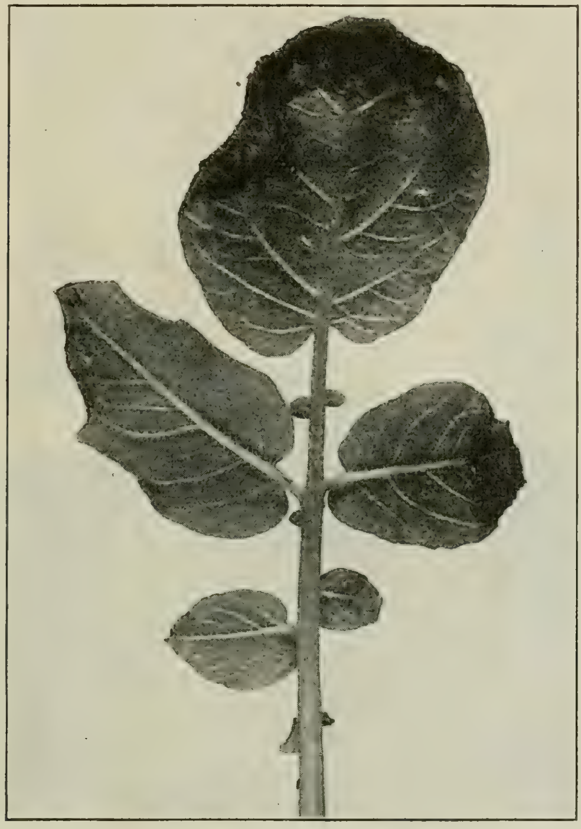

Fig. 4. Potato leaf showing hopperburn produced by leafhopper nymphs in greenhouse experiment with caged plants. Cast skins of nymphs are seen clinging to the leaf.

HOPPERBURN AND TIPBURN

The word "hopperburn" as a name for the specific injury caused by the leafhopper, *Empoasca mali* was coined at the December 27, 1918 meeting of the War Emergency Board[7], following the presentation of Dr. Ball's results to that body of plant pathologists. The possibility that not all burning injury of potato leaflets was due to the leafhopper led to the reservation of the general term "tipburn" for the condition of which hopperburn was a subdivision. Concerning the type of burning which occurs in Vermont (Lutman[4]) and Maine (Folsom and Schultz [9]), the writer is not attempting an opinion. It may be said that "hopperburn" and "tipburn," as shown by pictures and descriptions, are so similar that it seems impossible to differentiate them from the present statements in the literature.

Jones[3] and Lutman[4], who worked on the problem in the east, have reported that owing to the more severe drought conditions in the middle western states, Michigan, Wisconsin, Minnesota and Iowa, tipburn caused greater damage in those states than in Vermont. During the three years' investigation of the problem in Michigan, the writer has not been able to find any burning of the tips and margins of potato leaves which he could not associate with the potato leafhopper as the causal factor. If the insect itself was not found upon the leaf, cast skins of nymphs, egg pockets, or the eggs themselves were located. There is no doubt that hopperburn is the greatest factor reducing Michigan potato yields and that tipburn, if present at all, is of very minor importance.

THE POTATO LEAF HOPPER, EMPOASCA MALI LE B

DESCRIPTION

Adults: The adult leafhopper is a very active yellow-green insect about one-eighth of an inch long. It is distinguished from its near neighbor, *Empoasca unicolor* Gillete and other green leafhoppers by a row of six or eight white dots on the anterior margin of the prothorax and by the characteristic "H" marking on the mesothorax. (Fig. 5). The adult female is slightly larger than the male, from which it is distinguished

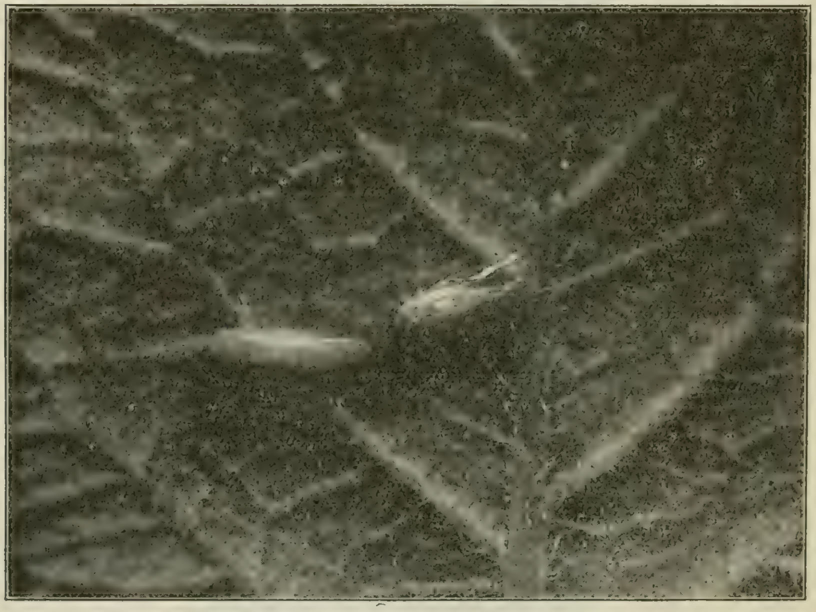

Fig. 5. Potato leafhopper adults (Empoasca mali LeB.) x 6. The white markings seen on the back of the insects are characteristics which identify the potato leafhopper.

by its genitalia—the female possessing a saw-like ovipositor. The adults are extremely active and fly at the slightest provocation. They are rarely seen by the casual observer during the early part of the season, but during August of favorable years they are seen to rise up in clouds as one walks down the rows of a potato field.

Eggs: The eggs of the potato leafhopper are minute pointed ovals approximately 1/32 of an inch long, and are usually laid in the midribs of the potato leaflets. Some of them may be laid in the leaf petioles and in the stems, but ordinarily the leafhopper female selects the more tender midribs for oviposition. When first laid, the eggs can be located only with great difficulty, but near the end of the incubation period their location can sometimes be recognized by slight blister-like elevations on the distorted midribs (Fig. 6). At this period, when viewed through transmitted light with the aid of a hand lens, the eye of the developing embryo shows up as a reddish dot in contrast to the hyaline or green color of the remainder of the developing nymph which cannot be differentiated from the surrounding tissue. Razor sections of an egg-blister at this stage reveal under the microscope a hyaline embryo with a red eye. (Fig. 7).

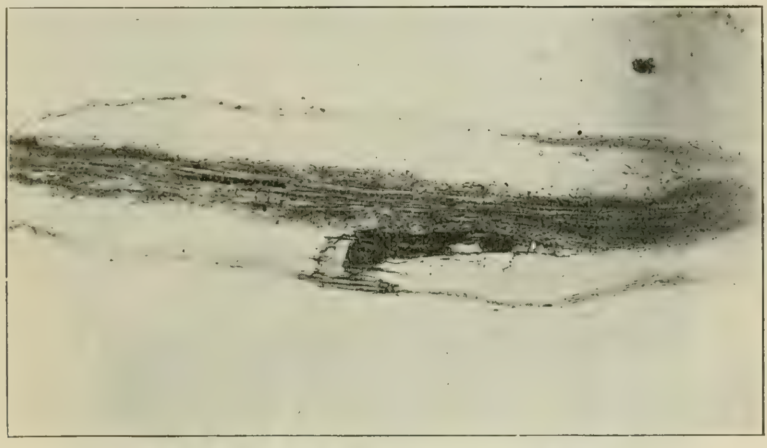

Fig. 6. Egg of potato leafhopper laid in midrib of potato leaflet.

Nymphs: The nymphs when hatched are less than 1/25 of an inch long and are white or almost hyaline. The red eyes stand out in striking contrast to the color of the remainder of the insect. Soon after beginning to feed, the nymphs take on a greenish color and during the course of growth the eyes become pearly white. During their growth the nymphs undergo five molts and the cast skins are often found clinging to the undersides of infested leaves. (Fig. 4). After the third molt rudimentary wings begin to develop. During the fourth and fifth instars the nymphs are able to hop from one leaf to another. On casting the last nymphal skin, the wings of the adult leafhopper are found to be curled upward in four separate rolls. The rolls containing the outer wings, or elytra, are transparent, while the rolls containing the hind wings are white. The elytra rolls unfurl about a minute after the insect has emerged from the nymphal skin, while the hind wings are not completely unfurled until about five minutes later. The characteristic markings of *Empoasca mali* do not appear on the young adult simultaneously with the casting of the last nymphal skin, but develop about two days later. The nymphs are active and when disturbed move with a peculiar sidling movement to the other side of the leaf. Both the adults and nymphs feed for the most part on the veins and veinlets on the undersides of the leaves (Fig. 8) and only occasionally are they found on the upper surfaces.

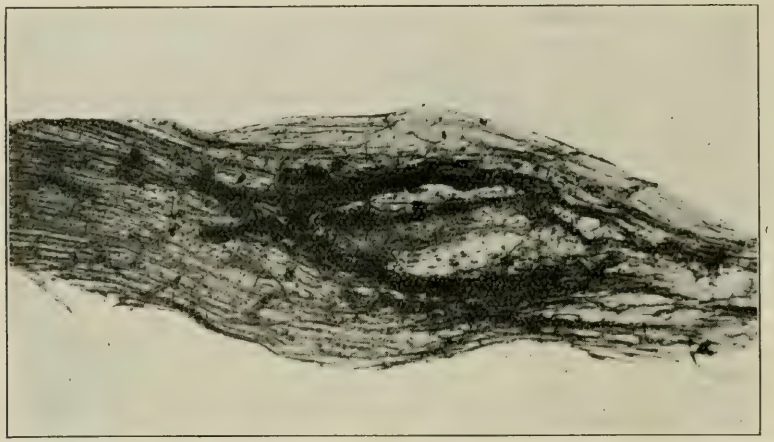

Fig. 7. Developing embryo of potato leafhopper in midrib of potato leaflet. (x 30.) (Photomicrographs by Miss E. McDaniel.)

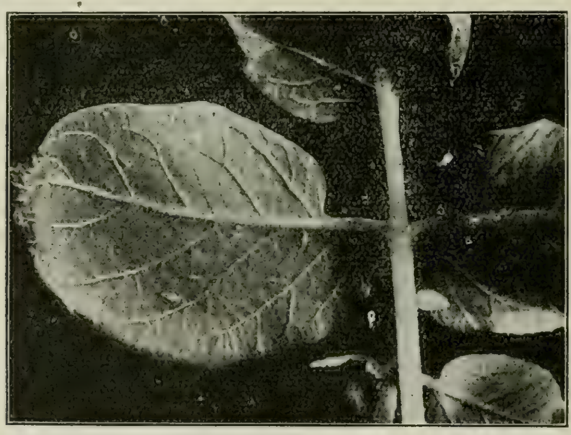

Fig. 8. Leafhopper nymphs feeding on under side of potato leaflet. (Natural size.)

LIFE HISTORY STUDIES

Control measures for insect pests are based upon life history studies of the pest in question. From such studies the time to combat the trouble most efficiently can be determined. Accordingly observations were made and experiments conducted to learn the mode of hibernation and the number of generations of the potato leafhopper under Michigan conditions.

HIBERNATION

Considerable difference of opinion has been expressed in the literature as to the manner in which this leafhopper passes the winter. Gillette[10] in Iowa, Lathrop[11] in New York, and Ackerman[12] in Pennsylvania, reported over-wintering adults, while Webster[13] in Minnesota, was of the opinion that the insect passes the winter both as an egg laid in apple twigs and as an adult.

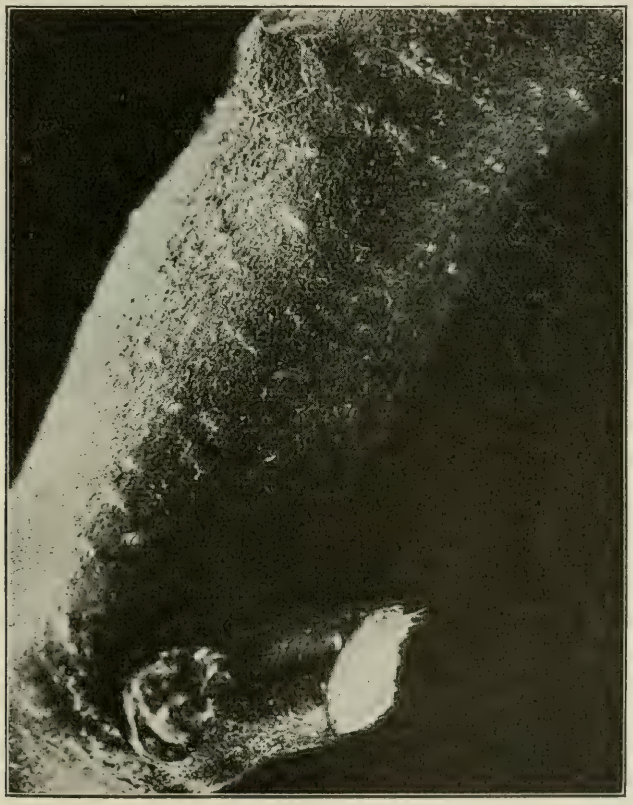

Fig. 9. Egg blisters of the rose leafhopper (Empoa rosae) and apple leafhopper (Empoasca unicolor) on apple twig. (Enlarged.) (Photo by Miss E. McDaniel.)

During the winter of 1919-20, six dozen apple twigs, varying in age from one to seven years, were brought in from the college orchard and placed in water in lantern-globe insect cages in the insectary of the Entomology Department. These soon leaved out and leafhopper nymphs hatched from eggs laid in crescent-shaped blisters, approximately 1/25 of an inch in length. (Fig. 9-10). The injury to the leaves which was

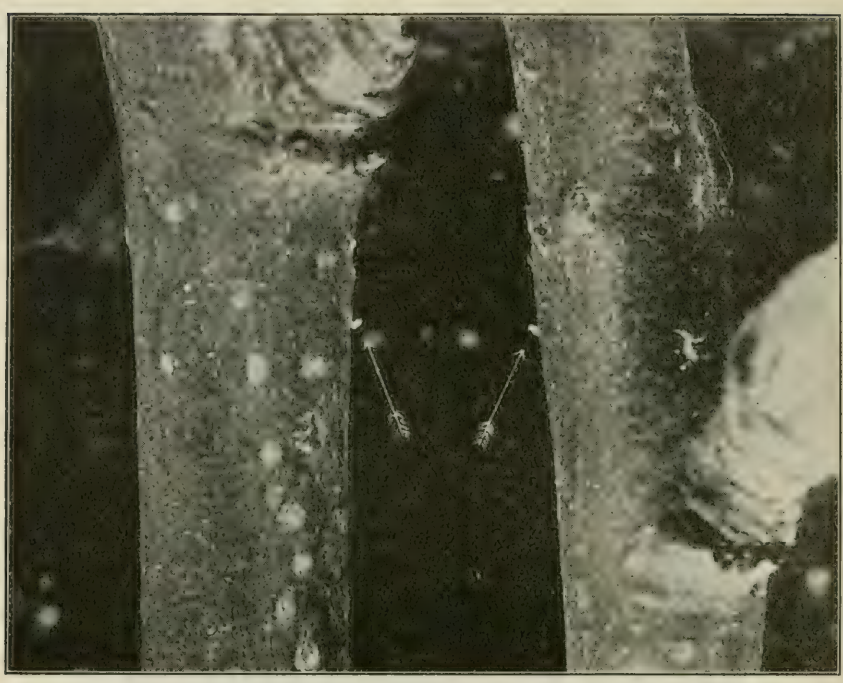

Fig. 10. Nymphs of the rose leafhopper hatching from apple. (Enlarged.)

caused by the feeding nymphs was of the stippling type which is characteristic of the apple leafhopper, *Empoasca unicolor* Gillette and the rose leafhopper, *Empoa rosae L.* Upon reaching maturity the majority of the nymphs proved to be the latter species. Only an occasional individual of the former species reached the adult stage. That these nymphs were not *Empoasca mali* was further demonstrated by placing thirty of them upon a young potato plant. The insects did not do well on this host and many of them died. The stippling type of injury, noted above, occurred upon one of the leaflets but there was no evidence of burning which characterizes the injury caused by the potato leafhopper.

In order to ascertain whether *Empoasca mali* laid its winter eggs on other trees, twigs were cut from various trees and shrubs growing on the campus, including maple, elm, oak, poplar, hawthorne, thornapple, elder berry, willow and rose. These were placed in water as in the case of the apple twigs. The insects began to hatch at about the same time that the leaves appeared and several species of Jassids and Membracids were noted. Aphids also hatched from surface-laid eggs. *Empoa rosae* was found to hatch from all of the twigs collected, showing that it has a large number of host plants. The species of the other leafhoppers were not determined except in so far as to be certain that they were not *Empoasca mali.* It seemed therefore that the leafhopper is not commonly carried over winter in the egg stage.

Observations on the campus, the orchard, and the college fields for the over-wintering adults began on March 16, 1920 and were made weekly until May 1, after which the field trips were made more often. During these observations trash in the college orchard and woodlot and along fence rows was carefully looked over. Sweepings were also made with an insect net.

On April 3, a species of leafhopper was collected in the woodlot which was of the same size and degree of delicacy as *Empoasca mali* and this led to the belief of the possibility of the latter also wintering over in the adult stage. The first specimen resembling the potato leafhopper was collected on May 7. This individual was green and had the characteristic white spots on the anterior margin of the prothorax, but did not have the white "H" marking on the mesothorax. Wing venation showed that the insect belonged to the genus *Empoasca*. Although the markings were not quite complete, it is quite probable that the specimen was of the *mali* species. The first authentic specimens of *Empoasca mali* were found on May 28. Twelve adults, all with the characteristic markings and wing venation were collected in a clover cover-crop in a young orchard.

That these leafhoppers did not come from early hatched eggs was shown by life history studies made on the rose leafhopper, *Empoa rosae*, which passes the winter in the egg stage. The first nymphs of this leafhopper to hatch outdoors from over-wintering eggs were observed on May 14. Three *Empoa rosae* nymphs were found on an apple tree in the orchard and one nymph was observed on a maple tree on the campus. A careful search for nymphs on other trees in the orchard failed to reveal further specimens. The average length of the nymphal period of the first generation nymphs of the rose leafhopper according to Ackerman[12], is 33.4 days, from which it is evident that the first nymphs to hatch from over-wintered eggs on May 14 could not have been more than in their second or third instars at the time when the first authentic *Empoasca mali* adults were collected.

The experimentation during the winter of 1919-20 and the collections and observations during the spring of 1920 indicate that the potato leafhoppers, *Empoasca mali*, hibernates in Michigan as an adult and not in the egg stage.

NUMBER OF GENERATIONS

Various investigators who have studied this leafhopper as a pest of fruit trees, particularly the apple, have made observations as to the number of generations during the season. Thus Washburn[14] in Minnesota, thought there were two and possibly three generations; Webster[13] recorded four generations for Iowa; Lathrop[11], two for New York, and Ackerman[12] reported three generations under Pennsylvania conditions.

In order to ascertain the number of generations of the potato leafhopper under Michigan conditions the lengths of the incubation and nymphal periods were determined by means of cages similar to those used in the greenhouse experiments. (Fig. 3). Young adult pairs were confined on caged potato plants and were removed when the first signs of egg blisters were found. The incubation period was determined as the length of time elapsing from the date the first egg scars were observed until the appearance of the first nymphs. In the two trials made, the incubation period proved to be 12 and 13 days respectively. Ackerman[12] found that the incubation period of *Empoasca mali* in Pennsylvania was from 7 to 9 days when the temperature averaged 76.89. The longer incubation period found under Michigan conditions is probably due to the cooler weather which prevailed, (62° F) and perhaps somewhat to the shading caused by the cages. The average nymphal period of six different broods was found to be 16 to 17 days. Under Michigan conditions, approximately a month elapses from the time a potato leafhopper egg is laid until the nymph develops to maturity and is ready to lay eggs for the next generation.

Assuming that the over-wintering adult leafhoppers migrate to potato fields about the middle of June and allowing a month for the development of each generation, it would indicate that there are two complete generations and a partial third generation on potatoes each season in Michigan. Nymphs of the third generation are no doubt killed by early fall frosts before reaching maturity.

EXTENT OF INJURY

The injury caused by the over-wintering adults and nymphs of the first generation is slight, owing to the small number of individuals present as compared to the leafhopper population of the second generation. The injury is also masked by the new leaves which appear on the rapidly growing vines.

The greatest damage occurs during the latter part of July and during August, because the leafhopper population by that time has increased greatly. For each over-wintering female which flies to the potato field in June there is a progeny of at least 450 individuals in the second generation, from which it can be realized that the leafhopper population during this period runs up into the millions per acre. When it is known that a single leafhopper nymph can cause the destruction of an entire potato leaf the damage caused by the millions of individuals on each acre of potatoes can well be imagined.

EFFECT OF TIME OF PLANTING

There appears to be a definite period in the spring during which the leafhoppers migrate from other hosts to potato fields. This migration occurs about the middle of June, and as a result eggs are deposited on the early-planted potatoes. That there is such a spring migration of leafhoppers was seen in a very striking manner during surveys of potato fields made in 1919 and 1921. Those fields in the Upper Peninsula which were planted during May and early June were very severely damaged by hopperburn, while fields in the same neighborhood which were planted after June 15th, remained green throughout the season. These observations were confirmed by evidence obtained on September 2, 1921, from the time of planting series at the Upper Peninsula Experiment Station which is tabulated on following page.

Table III. Effect of Time of Planting on Hopperburn, U. P. Exp. Sta., Chatham, Mich., 1921

Date planted	Variety	Per cent hopperburn
May 19	Green Mountain	100
June 1	Green Mountain	100
June 9	Green Mountain	75
June 16	Green Mountain	50
June 23	Green Mountain	25
June 30	Green Mountain	15

Hopperburn is not severe on late planted potatoes because the plants are either very small or have not come through the soil at the time the spring migration takes place, and remain practically free from leafhoppers until the flight of the first generation adults. This summer-migration occurs during the latter part of July and is obviously too late to cause extensive injury. Conditions for the Lower Peninsula were not worked out with respect to this migration.

These time of planting observations suggest a feasible method of combatting the leafhopper where danger from early fall frosts does not preclude late planting of potatoes.

WEATHER RELATIONS

Natural phenomena, such as the time of blossoming of fruit trees, date of emergence, and length of life cycle of insects, etc., are governed by weather conditions. It is well known that apple trees do not blossom on the same date every year. Likewise the time of emergence of insects from their winter quarters varies with the season.

It is intresting to note the weather relations of hopperburn during the three years covered by the present investigations. The departures from the normal temperature, precipitation, and sunshine during the months of April to August inclusive for these years are given in the table following.

Table IV. Departures from Normal Temperature, Precipitation and Sunshine in Michigan
+ = above normal; — = below normal

		1919	1920	1921
April	T.	+0.3°	—4.9°	+6.3°
	P.	+1.12″	+0.65″	+1.15″
	S.	—2%	—6%	+3%
May	T.	—0.7°	—1.1°	+3.6°
	P.	N	—1.91″	—1.48″
	S.	+6%	+14%	+7%
June	T.	+7.0°	+1.4°	+5.3°
	P.	—0.75″	+0.9″	—0.92″
	S.	+11%	+1%	+7%
July	T.	+2.4°	—3.1°	+7.0°
	P.	—0.86″	—0.01″	—0.62″
	S.	+8%	—1%	+5%
Aug.	T.	+0.5°	—0.4°	+7.0°
	P.	—0.5″	+0.09″	+1.29″
	S.	+1%	+1%	+1%

T = Temperature; P = Precipitation; S = Sunshine

The 1919 season was considered approximately normal so far as the spring advance was concerned. Duchess apples were in bloom at East Lansing on May 14 and leafhoppers emerged at their normal period. The season made rapid progress in June, and, as is seen from the table of departures shown above, the temperature and sunshine were much above normal while the precipitation was below normal for the month. Similar conditions prevailed during July but in August these became more nearly normal. Favorable weather conditions were presented during June and July for the development of leafhoppers and resulted in serious damage from hopperburn during the season.

Contrasted with 1919, the 1920 season was backward. Apples were in bloom at East Lansing on May 21, a week later than the preceding year. The season did not advance rapidly in June owing to the fact that the temperature and sunshine were only slightly above normal, while the precipitation was almost an inch above normal. July was characterized by cold, cloudy weather with average rainfall, while August as in the preceding year was more nearly normal. The weather conditions during this year were not favorable to leafhoppers. The backward spring resulted in late emergence of the over-wintering adults, which coupled with the cold, wet weather of July prolonged the incubation periods of the leafhoppers so that these insects did not become abundant and hopperburn was not an important factor during the season.

The 1921 season was the most advanced of the three seasons and apples were in bloom at East Lansing on April 26, approximately two weeks before the 1919 season and almost a month before the 1920 season. June temperature and sunshine, as in 1919, were much above normal while the precipitation was below normal. Similar conditions prevailed in July, whereas in August the temperature and precipitation were above normal while the sunshine was slightly below normal. Conditions during this season again were favorable to leafhoppers. The insects emerged early and under the hot, dry weather conditions the life cycles were shortened. The first nymphs to hatch out on potatoes at the Upper Peninsula Experiment Station were observed on July 5 as compared to July 22 when the first nymphs were observed hatching in 1920. Leafhoppers were abundant in 1921 and hopperburn became severe during the season. The timely rains which came during August saved the potato crop from greater injury.

Although the above observations cover only a period of three seasons, they seem to indicate that whether or not hopperburn will be serious during a given season can be predicted. *Hopperburn can be expected to be serious during seasons which follow an early or normal spring during which the month of June is characterized by temperature and sunshine "above normal" and "below normal" rainfall.*

RESISTANCE OF VARIETIES.

During a survey made of potato fields during the latter part of July, 1919, observations were made as to the resistance of varieties to hopperburn. It was repeatedly noted during the survey that early varieties were more susceptible than late varieties. Observations made on the variety plots at the Upper Peninsula Experiment Station, all of which were planted on the same day, confirmed the findings of the survey. Of the early varieties, Bliss Triumph was found to be the most susceptible and was followed in order by Early Ohio and Irish Cobbler. The Idaho Rural was found to be the most susceptible of the late varieties and was followed in order by Green Mountain, Russet Burbank and Rural New Yorker. Although some burning has been observed on the Rural New Yorker variety, it has some inherent quality whereby it is able to withstand insect and disease attacks better than other varieties. This resistant quality of potatoes of the Rural type makes them very popular with the potato growers.

SELECTIVE PREFERENCE OF THE LEAFHOPPER

The 1920 season which was unfavorable to leafhoppers presented an opportunity to make observations on the type of vines selected by the over-wintering adults for egg laying. Owing to the small number of adults seen in the spring a large number of hills were carefully examined for nymphs during the summer months. As a result of these examinations it was found that vines which were healthy were usually free from leafhopper infestation, while nymphs were always found on vines which were affected with the mosaic disease. The brighter green color of the diseased hills perhaps attracts the over-wintering adults and result in a greater number of eggs being laid on those vines.

HOST PLANTS

The potato leafhopper has been collected from a great number of plants, but doubtless many of these are not true host plants for the insect, that is, plants upon which the leafhopper lays eggs. Ackerman[12] reports that eggs of *Empoasca mali* have been found in the leaves of apple, pear, peach, plum, quince, cherry, alfalfa, beet and potato. In addition to these the writer has found that the insect also lays eggs on beans, sunflower, red clover and curled dock (*Rumex crispus*). It is common knowledge that weeds in a potato field, by virtue of their stronger root systems, rob the potato vines of plant food and cause material reducation in the yield of potatoes. This in itself is of sufficient importance to warrant weed eradication, but when this knowledge is further augmented by the fact that the destructive leafhopper breeds on weeds the eradication of these plants becomes imperative.

PRESENT STATUS OF INVESTIGATIONS

While this work was in progress Ball continued his investigations (this time working in Iowa) assisted by Fenton[7]. Dudley and Wilson[15] worked on the problem in Wisconsin. The results obtained in both of these states agree with those obtained under Michigan conditions and all together offer very tenable proof that the injury to potato foliage in the middle western states is not "tipburn" due to excessive heat and sunshine, but is "hopperburn" caused by the potato leafhopper, *Empoasca mali.*

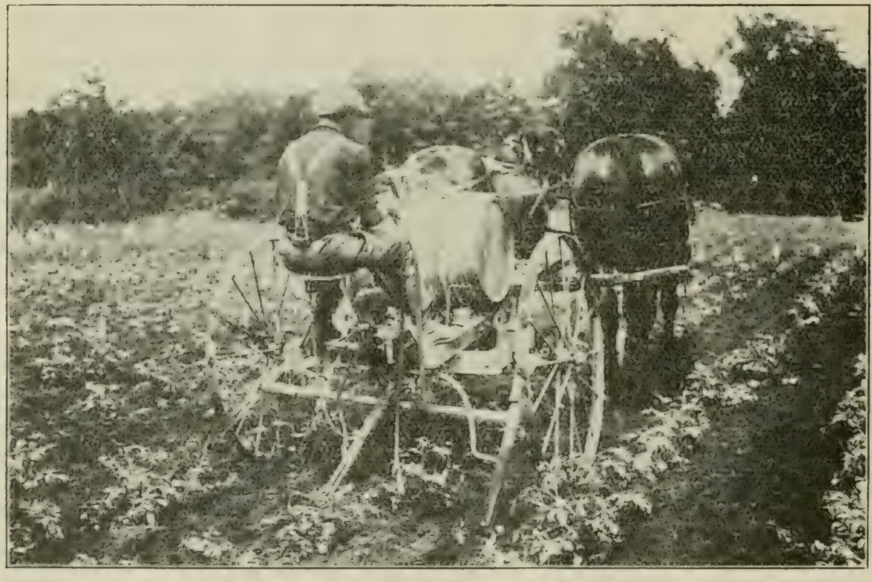

Fig. 11. A remodeled traction type sprayer. While better than no sprayer, this type does not maintain sufficient pressure for best control of hopperburn.

PREVENTIVE MEASURES

The first evidence of the control of "tipburn" by means of bordeaux mixture was presented by Prof. Goff[1] in 1891. In testing this spray for the control of late blight he reported that the check rows turned yellow and later became brown, while the sprayed vines remained green all through the season. He also noted that "none of the potatoes were decayed at digging time and that there were no indications that the blight which so injuriously affected the foliage of potatoes the past season on the checkrows of our experimental plot and throughout southern Wisconsin was connected in any way with the potato-rot fungus, *Phytophthora infestans*. But whatever the affecting disease was, it is evident that the treatment proved the remedy for it." Investigations since that time (Stewart[16], Lutman[4]) have confirmed Goff's findings and it is repeatedly noted in the literature of bordeaux mixture as a potato spray that the percentage of tipburn is always reduced in the sprayed plots.

In order to ascertain what effect, if any, bordeaux mixture had on the control of hopperburn, spraying experiments were conducted at the Upper Peninsula Experiment Station, Chatham, Michigan, during the 1919, 1920 and 1921 sessions. A 5-5-50 bordeaux mixture, to which an arsenical poison was added to control the Colorado potato beetle, was used during the first two seasons, the spray being applied with a 50-gallon traction type sprayer, (Fig. 11) which was remodeled so as to apply the spray to the under sides of the leaves. During the 1921 season a 4-4-50 bordeaux mixture was used, and was applied with a power sprayer which was capable of maintaining a pressure of 225 pounds (Frontispiece).

The results obtained from the three-season spraying program are summarized below

Table V. Effect of Bordeaux Mixture on Hopperburn

Spraying Experiments, U. P. Experiment Station, Chatham, Michigan, 1919, 1920, 1921

Season	First application	Size of vines first application	Times sprayed	Results	
				Not sprayed	Sprayed
1919	July 3	9″	4	Aug. 15 vines dead from hopperburn.....	Aug. 15 vines still alive but hopperburn severe.
1920	July 7	3–9″	5	Vines green all season. 27.7% hills showed slight hopperburn.	Vines green all season. 1.7% hills showed slight hopperburn.
1921	July 8	3–6″	5	Sept. 9 100% hopperburn and early blight. Vines dead Sept. 15.	Sept. 9 hopperburn not evident. Early blight caused death of vines Oct. 10.

*5-5-50 bordeaux mixture used in 1919, 1920; 4-4-50 in 1921.

Some very interesting facts were gleaned from the three-year spraying experiments. The 1919 and 1921 seasons were very favorable to the potato leafhopper and hopperburn caused serious losses. The 1920 season, on the other hand, was two weeks later than normal and rainfall was abundant. Leafhoppers emerged late and multiplied very slowly with the result that hopperburn was not severe at any time during the season.

Only partial control was obtained in the 1919 experiments. This was due to the inefficiency of the sprayer which was used. The pressure of approximately 50 pounds which the outfit was capable of maintaining was not sufficient to cover the vines adequately with the spray. That a poor outfit is better than none at all was shown by the fact that the sprayed vines remained alive about two weeks longer than the unsprayed plots. The experiments conducted during the 1920 season showed a difference of 26 per cent of hills affected with hopperburn in favor of spraying with bordeaux mixture. The first nymphs to hatch under the 1920 Upper Peninsula conditions were observed July 22, and counts made on the sprayed and unsprayed plots on July 30, revealed comparatively few leafhopper nymphs. Only an occasional hill in the sprayed plots revealed nymphs, and these averaged about three nymphs to a hill. The insects were more numerous on the unsprayed plots and more hills affected. The average for the unsprayed plots was nine nymphs to a hill. No burning was evident at the time the observations were made.

The 1921 season was ideal for spraying experiments for hopperburn control. The season opened early and the potato leafhopper got an early start. Hot dry weather prevailed during the growing season which permitted rapid multiplication of the insect. By means of the power sprayer which was used during this season the vines in the sprayed plots were kept well covered with bordeaux mixture. Observations made on September 9, showed the unsprayed vines rapidly dying as a result of hopperburn, while the sprayed plots were still green. (Fig. 12).

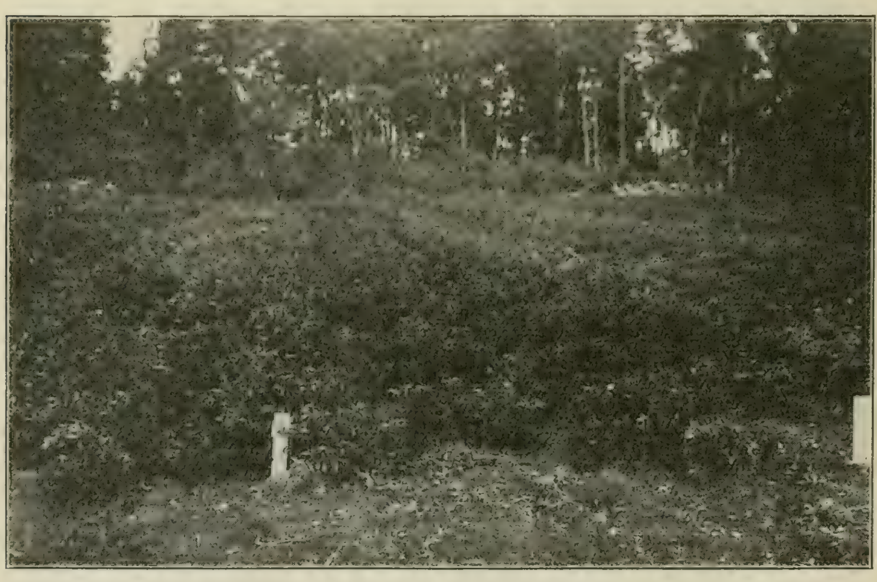

Fig. 12. 1921 spray plot. The sprayed vines remained green while those which were unsprayed had a decided brownish cast due to hopperburn. Photo taken Sept. 9, 1921.

Bordeaux mixture does not kill the leafhopper but merely acts as a repellant. Vines covered with bordeaux mixture are not relished by the leafhopper and the insect flies to other hosts or to other potato fields which have not been sprayed.

DUSTING EXPERIMENTS

Preliminary experiments with various dusts were conducted during the 1921 season to ascertain what effect they had on hopperburn and leafhopper control.

A dehydrated copper sulphate and lime dust was applied with a hand dusting machine to two rows of potatoes in the spray plot at the Upper Peninsula Station. Four applications were made during the season. On September 9, the dusted rows showed conspicuously more vigorous vine growth than the checks which had had no treatment. (Fig. 13). The foliage of the dusted rows was deep green in color while that of the check rows had a decided brownish cast due to hopperburn. The dusted rows also compared very favorably with those which were sprayed with bordeaux mixture.

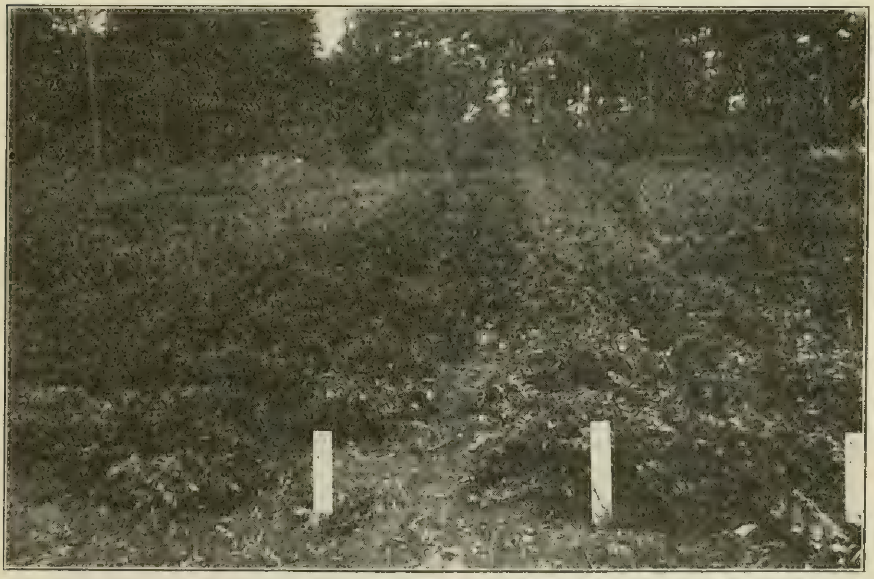

Fig. 13. 1921 dust plot. Dehydrated copper sulphate and lime dust kept the vines green and in vigorous growing condition Photo taken Sept. 9 1921.

In addition to the above experiments, trials were made with dusts impregnated with nicotine to determine effects upon the leafhopper. Black leaf 40 was used as source of nicotine. Dusts were made containing two and three per cent of this product, which interpreted in terms of nicotine would be .8 and 1.2 per cent respectively. The dusts were applied by means of a hand dusting machine. Six hills were dusted at each trial, and the insects which dropped from the vines were collected on sheets of wrapping paper which were spread underneath the vines before the dusts were applied. The insects which dropped onto the paper were not collected until 30 minutes after the dusts were applied in order to allow any insects which were not killed to escape. The effectiveness of the dusts is shown in the accompanying counts of leafhoppers.

Table VI. Effect of Nicotine Dusts on Leafhopper Control, 1921

Treatment	No. trials	No. hills dusted	Number of Empoasca mali dropped			
			Nymphs	Adults	Total	Av. per trial
Sulfur—2% BL 40	4	24	1,078	286	1,364	341
Sulfur—3% BL 40	4	24	1,209	302	1,511	377
Lime—2% BL 40	3	18	925	142	1,067	355
Copper-lime—2% BL 40	5	30	1,182	221	1,403	280
Dehydrated copper-sulphate—2% BL 40	3	18	48	25	73	24

In addition to the leafhoppers, the impregnated dusts killed great numbers of plant lice (aphids). The trials were made too late in the season to determine the effect on hopperburn or to determine whether the dust had an injurious effect upon the foliage. Although these preliminary dusting trials show encouraging results, the practice in addition to the greater cost has not yet passed the experimental stage and cannot be recommended to replace spraying with bordeaux mixture.

SUMMARY

Three years' study of the burning injury of potato foliage in Michigan has shown—

1. Hopperburn is one of the greatest factors reducing Michigan potato yields during dry seasons.
2. The injury is caused by the potato leafhopper, *Empoasca mali.*
3. The insect passes the winter in Michigan as an adult, emerges during May, flies to potato fields about the middle of June, and lays eggs on the vines.
4. There are two complete generations each season in Michigan approximately one month elapsing from the time the eggs are laid until the nymphs hatch and develop into adults.
5. Time of planting has a marked effect on amount of hopperburn in a field. Fields planted after June 15, in the Upper Peninsula showed very little injury.
6. Early varieties are more susceptible to hopperburn than late varieties. The rural types seem most resistant.
7. The insect is repelled and hopperburn is controlled by spraying the vines with 4-4-50 bordeaux mixture.
8. Dehydrated copper sulphate and lime dust and dusts impregnated with nicotine give some promise for control of hopperburn and the leafhopper, but cannot yet be recommended to replace spraying with bordeaux mixture.

RECOMMENDATIONS

For efficient control of hopperburn it is necessary that the spraying program be started before the over-wintering adults have migrated to the potato fields.

The first application of bordeaux mixture should be made when the vines are from 3 to 6 inches high, and should be followed by the second spraying about a week later. At least three subsequent applications should be made at intervals of 10 days or 2 weeks.

Best results are obtained by using a sprayer which is capable of maintaining a pressure of 200 pounds or more and which is equipped with a boom so arranged that two nozzles direct the spray upward and inward from each side of the row, while a third nozzle directs the spray downward and covers the upper surface of the leaves. It is important that the undersides of the vines be kept well covered with bordeaux because it is there that the leafhoppers feed.

Spraying potatoes with bordeaux mixture is a form of insurance in which every potato grower can afford to invest. It pays annual dividends of increased yields. During wet seasons bordeaux mixture saves the crop from the ravages of late blight, while in dry seasons it turns the tables on hopperburn.

The above recommendations should be supplemented by thorough eradication of weeds in and surrounding the potato field in order to remove sources of later infestation.

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